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Engineering News-Record

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Dual highway near Paterson, New Jersey

Modern Highway

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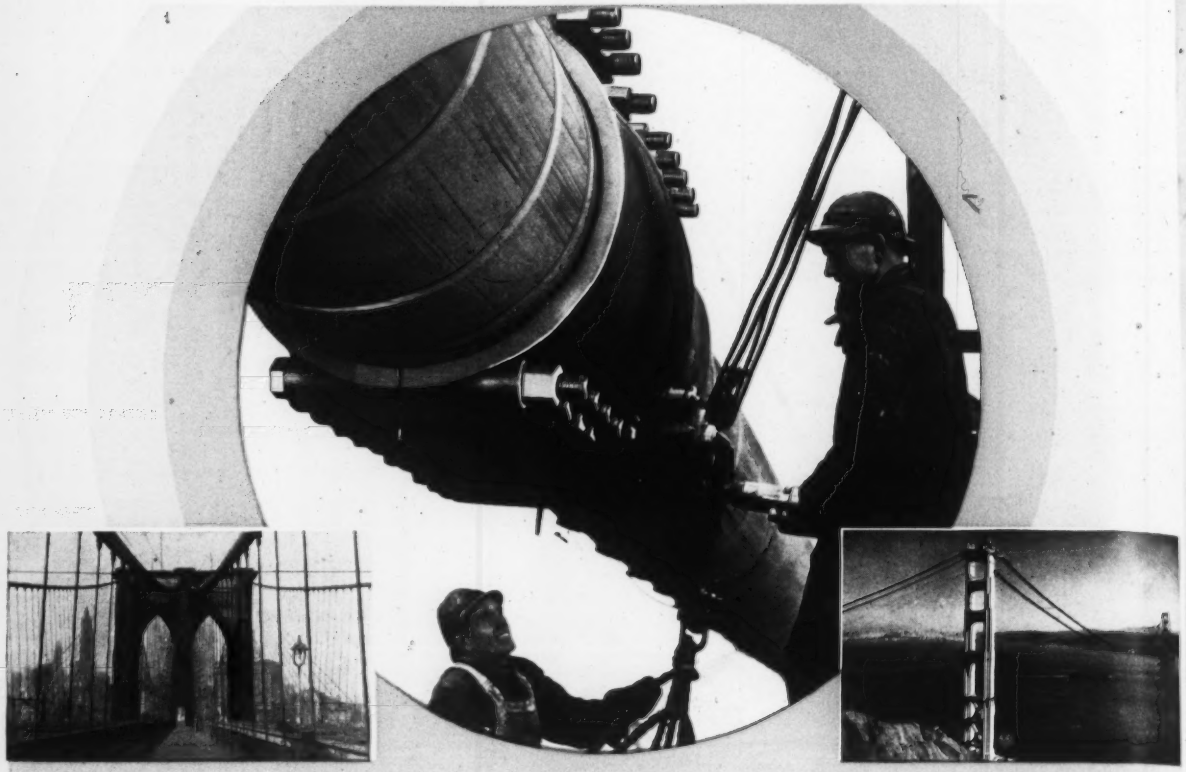

A TALE OF TWO BRIDGES

● When the four 15¾" cables that suspend the famous Brooklyn Bridge were swung from the supporting towers across the East River in the late seventies, it marked a real triumph in the engineering world. Upson iron bolts and bolt ends were used to hold the supporting cables.

Today, on the other side of the continent, the Golden Gate Bridge is fast taking shape. Its span is more than two and one-half times as long as the main span of the Brooklyn Bridge. Its cables are 36 inches in diameter. But Upson bolts and nuts are again being used. This time to attach the hold down cable bands to the main cables and to fasten various types of cable clamps.

Unlike those in the Brooklyn Bridge, these bolts are not merchant iron. Bridge designers, like engineers in every other industry, today demand the finest alloy steel where safety must not be compromised. They are two and one-half inches in diameter with lengths up to more than three feet. They are husky bolts with a serious duty ahead of them for many generations.

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THE HIGHWAY *Comes of Age*

THE annual convention of the American Road Builders' Association again focusses attention on the problems and prospects of the highway industry.

Today the observer of highway conditions senses a substantial change in the outlook. That change is for the better. Not so long ago many of our people were half convinced that the road building job was about completed. From now on, they thought, it will be a matter of maintenance only.

This error was zealously fostered by groups interested in the public functions that do not produce revenue. To them the highway revenues appealed as a juicy and tempting morsel. The fact that those revenues were earmarked, always morally and often legally, for highway improvement exclusively meant nothing to the raiders or to some public officials who lacked the stamina to demand straightforward taxation to meet their legitimate needs.

These active attacks on highway improvement were helped by the passive attitude of the vast army of citizens most directly and vitally concerned. And with this combination of aggressive attack and feeble defense, it looked, just a few short years ago, as though American highway development was due for a staggering setback.

From this it was saved by the successful efforts to have road work take its very effective place in the federal emergency works program. And although this gave rise to some unfortunate excursions into day-labor and primitive methods, it is well to remember that these are but temporary evils and that the emergency program probably saved the industry from more or less complete collapse.

TODAY the outlook is much brighter. With the growth of public revenues through business recovery, the raids on highway revenues will tend to diminish. Daily driving over inadequate roads is bringing home to every motorist the fallacy of the "over-built highways" propaganda. The mounting toll of accidents drives home the hazards of the obsolete highway. The economic and social values created by motor transport are understood by more of the people who now see the efforts to obstruct its progress for what they really are. Farmers living on thousands of miles of unimproved roads want to know when they will be connected up with the trunk net-work. Taxpayers are becoming more critical of the cost and waste of day-labor relief work.

But most heartening of all is the new spirit of militant unity that inspires those who have a stake in motor transport. The motorist is on the warpath and is making himself felt at the polls. The millions who earn their bread producing, selling and servicing motor cars, accessories, tires and gasoline, the operators of buses, trucks, garages and filling stations and many others are coming to understand that the modern, thoroughly adequate highway is essential number one in their very existence. They know that the surest way to obstruct automotive progress is to throttle highway development.

ALL these are coming to see that the highways are *their* highways, in which they have a huge investment. They are learning that they can protect this investment only as they maintain their highways in first-class shape and as they extend and improve them to meet expanding needs. They are learning that the cost of owning and driving their cars also depends on how well they do that job. They have come to see that the first requirement of highway safety is a safe highway.

So they are cracking down on the misuse of the taxes they pay to improve their highways. Some have amended their state constitutions to end that abuse; others are moving to that end. The highway users and the motor transport industry in all its branches today are awake and becoming conscious of their strength.

So, in this new spirit and with these new allies, the highway industries must carry on with redoubled energy. Now that they are pulling with the tide their efforts will be more productive. But on no account should they relax those efforts.

The New Orleans convention may well mark the point at which American highway improvement passes definitely from the formative stage into its maturity as a recognized element of modern motor transport. As such it becomes an enterprise of vital concern to the millions engaged in that far-flung activity.

Willard Chevalier

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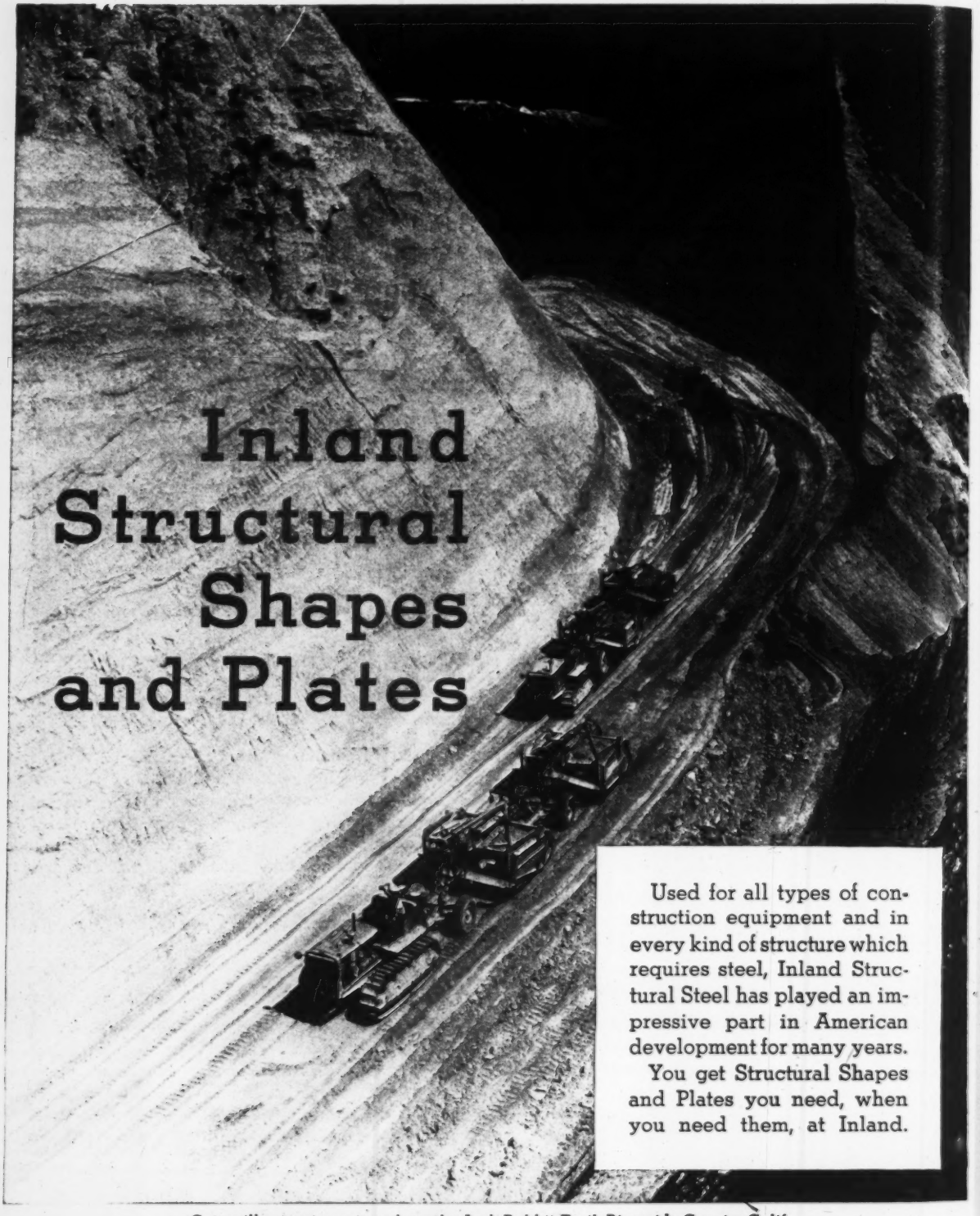

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Eighty-five Miles of Tunnels— New York is beginning work on the Delaware water-supply project. A major element is the tunnel aqueduct 85 miles long. Next week's issue will describe the preliminary shaft sinking work, and engineering details of the five contracts on which bids will be taken.

AMERICAN TIGER BRAND IS USED TO *rough going*

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ENGINEERING NEWS-RECORD

Annual Highway Number—January 7, 1937

Highway Engineering Today

WITH the present year highway development enters the third decade since federal aid first placed it on an efficient basis, under joint federal and state direction. Marvels have been accomplished during the twenty years. The road of today is the creation of that short period, the product of keen, unremitting, toilsome labor of men in field and laboratory.

The progress made is continuing, and by every indication will continue, but not wholly along the lines followed in the past. The art faces a definite change in objective. Heretofore the highway engineer concerned himself primarily with excellence of road structure. Now, without relaxing attention to structure, he finds that he must give first consideration to road operation. Safety and efficiency of operation will control all road planning and roadbuilding from this time on.

HOW well is the art of highway engineering equipped to meet the new responsibility? Wherein can it be improved, and what means of improvement are at hand? To give the answer to these questions, *Engineering News-Record* has obtained the views of an able group of highway engineers and students, and presents them to the highway fraternity in this issue. Their analysis of current practice and their comment on its shortcomings should help to mark out the course of the coming advance more definitely. In effect they forecast the highway engineering art of the next decade.

Altogether, an encouraging picture is presented with respect to the main features of road design. Highway engineers evidently are already conscious of the new service demand. Their current standards embody refinements in respect to curvature, visibility, roadway dimensions and lane and access arrangements that exceed anything known in the past. Many details remain to be improved, no doubt, but already the best standard is far in advance of average practice and immeasurably ahead of the general level of service quality of existing roads.

THUS, the art is well equipped for its new responsibilities. Not only are its standards better but it has vastly better tools than ever before. Rational design is far advanced. Well-tried methods of analysis, extensive research into the qualities and weaknesses of road materials, and, not least, a growing knowledge of the behavior of soils in the foundation and the body of the road, are at the highway engineer's command. These new tools are rapidly doing away with his past dependence on trial and error. Even the keen appraisal of modern practice that is presented in the following pages scarcely does justice to the excellence of the modern highway designer's equipment.

The work that remains is to put our present high standards and excellent equipment to full use—to improve them constantly, but always to make sure that they find thorough application in the continuing development of our road transportation system. The future service of our roads will be measured by how well the roadbuilders of today utilize the full power of the highway engineering art.

Design for Maintenance

Present-day road design makes advance provision for ease of upkeep and future revision and enlargement—Closer coordination of design with maintenance will reduce costs and make roads better and safer—Regional problems call for special considerations in plans for the future

PRESENT PRACTICE *reviewed by* . . . . . H. E. SURMAN, *Engineer of Design, Illinois Highway Department*
DEFECTIVE PRACTICES *outlined by* . . . . . B. H. PETTY, *Professor of Highway Engineering, Purdue University*

EDITOR'S INTRODUCTION

CORRELATING highway design and maintenance is an idea of recent birth. Advance provision for future enlargement to fit growing traffic requirements is still more recent. Present conditions make both fundamentally important as factors in efficient highway practice.

Systematic highway maintenance dates back only twenty years to when federal-aid legislation required as a condition of federal investment that the roads improved by its help must be adequately maintained. The maintenance department first organized by the states were long held secondary to those directing construction. Then difficulties of keeping roads in shape to serve growing traffic made it clear that design and construction had to plan in advance for easy upkeep and possible enlargement. Today this is general practice.

A striking picture of the changed methods is presented in the first of the following discussions. Even ten years ago such listing of design considerations would have been impossible. Yet the picture that follows shows that much more still remains to be done.

Highway Upkeep Recognized In Current Design.....*H. E. Surman*

A SAFE ROAD is the first requirement of highway design. After safety is provided for, future maintenance and rehabilitation are the most important considerations of the designer. This doctrine has developed slowly, but it is now universal.

Present practice among state highway departments may vary widely in many details of design, but all are giving attention to those features that make it easier and cheaper to maintain the highway and later rehabilitate and widen it to provide for future increase in traffic. Today, for example, the design engineer is keeping clearly in mind that right-of-way and roadbed are the only permanent components of the highway, and that these are permanent only if the right-of-way is wide enough to meet any forecast of future needs, and only if such design elements as grades, horizontal curves, superelevation and sight distance take into account future highway speeds.

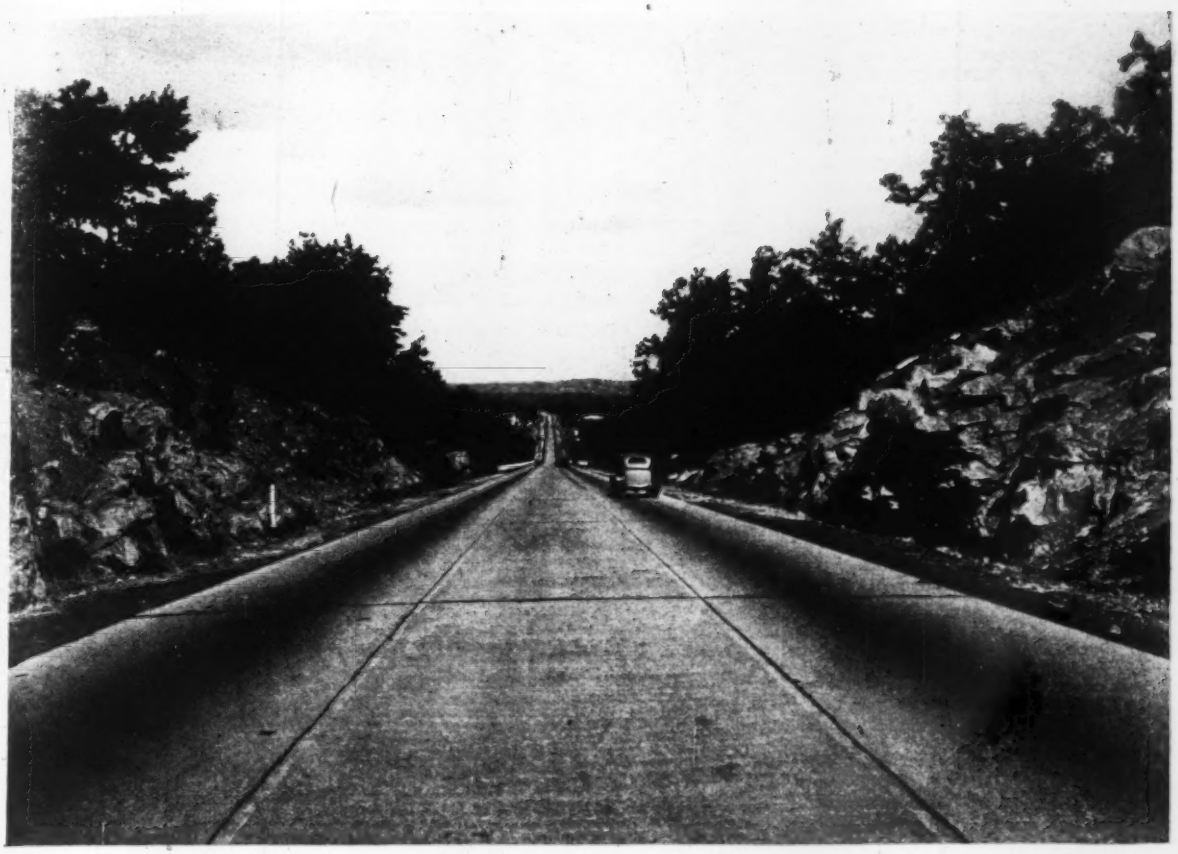
And be it noted here that the chief reason why so many of our main highways are obsolete is the low-limit speed laws of the past. Now that most states have either removed or materially raised minimum speed requirements in rural areas, the more progressive states are designing the main roads for speeds considerably in excess of those prevailing today. This is the only way in which full consideration can be given to future rehabilitation while keeping the cost of maintenance within reasonable limits.

Looking to the future

To state the present situation in its broadest terms, highway departments are meeting the maintenance and rehabilitation problem by (1) providing minimum right-of-way widths of 100, 150 and 200 ft. for two-, four- and six-lane pavements and (2) construction by stage methods when necessary and replacing, resurfacing or widening when traffic demands it, without losing the original investment in right-of-way roadbed and drainage structures.

Next, to consider the chief detail elements of design practice, pavement location is given more attention to facilitate maintenance and rehabilitation. Where, for example, present traffic is developing rapidly enough to justify a forecast that four or more lanes will ultimately be needed to accommodate it, it is accepted practice to construct initially a two-lane pavement located off-center, to provide for a dividing parkway at least 30 ft. wide when additional lanes are paved. In location, also, good practice seeks a route that will facilitate future separation at railway crossings and important intersecting roads.

In designing the pavement structure itself, consideration is given to adopting the proper width, thickness and smoothness to carry the contemplated volume and weight of traffic at low maintenance cost. Other design measures to reduce maintenance are: Installation of longitudinal joints separating traffic lanes so that longitudinal cracks will be minimized and the use of transverse expansion joints to reduce internal stresses so that blow-ups and heaving will not occur during hot weather; constructing concrete gutters on the inside edge of curves that are superelevated more than $\frac{3}{4}$ in. per foot, and on grades exceeding 3 per cent, to prevent rutting and to handle the surface drainage; rolling or tamping earth fills to prevent subsequent settlement of the pavement; placing underground drainage systems in cuts to prevent rise of groundwater and the resultant heaving of pavement in cold weather; and replacing unsatisfactory subsoil materials, such as peat, loess



THREE-LANE HIGHWAYS in particular call for long sight distances; stabilized shoulders reduce the hazard of run-offs; current practice dictates a smoother backslope to make the full shoulder width available without risk of injury.

and silt, with good earth or gravel as a safeguard against subsidence of the pavement.

Going outside the paved area, present practice also takes into account the maintenance of the parts of the roadway that are off the pavement. The more important items provided are: flat slopes of 1 on 3 or 1 on 4 to reduce the amount of guard fence required and to permit mowing vegetation by machinery; sodded slopes, to prevent erosion; adequate drainage structures to prevent washouts; slope wall or riprap protection of fills to avoid washing during high water; in metropolitan areas, underground drains, to eliminate side ditches; in the northern states, grade line raised several feet above the surrounding land and cuts widened to prevent snow blockades; location that avoids hillsides as far as possible to prevent interference by slides; stone, gravel or shale surfacing along the edges of uncurbed pavements carrying heavy traffic as well as on the approaches to all intersecting roads, farm entrances and mail-box approaches to prevent the rutting of shoulders and tracking of earth from the shoulder onto the pavement.

Coordination of Design and Upkeep is Lacking

Ben H. Petty

HIGHWAY officials have been slow to realize the close interrelation of highway location, design, financing, construction, maintenance and operation. Experience demonstrates that efficient, economical and relatively safe highway transportation will not be obtained unless all these factors are considered together; yet the idea remains that they can be handled by virtually independent, non-cooperating departments. This policy often generates friction and ill feeling between departments and always is a serious handicap to their effective functioning in developing the highway programs.

The value of cooperation is apparent from the fact that a designing engineer can improve his technic by practical experience in construction, maintenance and operation; that a locating engineer gains from experience in the problems of the designer, the constructor and the maintenance man. Completely separating these departments without assuring coordination simply invites delay, inefficiency, abnormal expense and public criticism.

The relationship of design to maintenance and rehabilitation is especially important. It may be illustrated by specific examples relating to pavement structure, to traffic-service qualities, and to type of road. In each case it will appear that maintenance is collateral to design for other objectives.

Structural factors

The air waves and the press these days are full of accusations that engineers have failed to build safety into the highways. Much of this criticism should be dismissed with scant consideration, but there is truth in the statement that engineers could build more safety into their roads if they would build to *reduce maintenance costs.* This charge applies particularly to short-radius horizontal curves, inadequate superelevation, vertical curves with short sight-distance and narrow right-of-way.

Unstabilized Shoulders—A design practice that results in much maintenance expenditure is the use of un-

stabilized gravel or stone along the edges of the pavement, or the use of no metal at all. On 18-ft. pavements, especially where dual tires are used on trucks, the outer tires get off the pavement in passing other vehicles and develop ruts which sometimes attain depths of 6 in. and create both a serious traffic hazard and an annoying maintenance task. This trouble occurs to some extent on 20-ft. pavements, and some engineers are constructing 22-ft., two-lane pavements where much bus and truck traffic is involved. Whether this will answer the purpose of preventing ruts is still open to question, but there is an opportunity for the designing engineer to reduce maintenance costs and also reduce accident hazard by widening the slab or specifying some type of shoulder stabilization adjacent to the pavement.

Pavement Joints—The maintenance of joints in concrete pavements becomes an increasingly costly operation as pavements grow older. True, we have not yet developed the perfect joint, but many greatly-improved types are now on the market that justify their cost by subsequent reduction in maintenance expenditure. Improperly designed joints use up excessive amounts of bitumen in joint-filling operations once or twice a year, and in many cases these poorly-designed joints tend to cause spalling that extends several inches back from the joint. The resulting wedge-shaped depressions are expensive to fill and maintain; unless adequate dowel bars are specified at rather short intervals, load transference across the joint is greatly reduced, which may result in cracks at these overloaded edges. Apparently no method has yet been devised for making joints watertight, and until such development occurs we will never secure a perfect joint.

Snow Removal—In sections where snow removal is a major maintenance operation the designer can so locate and construct his grade as to minimize the formation of drifts on the highways. The removal of snow can be facilitated through a design calling for ample right-of-way width to provide storage space for snow moved off the traveled way. The proper selection and location of guard rails can also aid in facilitating snow removal. Judicious planting of trees and shrubs on wide right-of-way tends to prevent the formation of drifts on the road.

Drainage—Occasionally the designing engineer seems to forget entirely about the importance of drainage in developing a satisfactory highway. Here again ample right-of-way is necessary; surface drainage ditches must be placed far enough away from the pavement edge to give a gradual slope into the bottom of the ditch. Not only will this reduce water but it will permit cars out of control to run into the ditch without excessive danger. Some designers specify no ditch at all, or one of inadequate depth below the surface of the pavement. The writer believes that surface ditches are highly essential—except, of course, where the subsoil conditions make them unnecessary or where adequate subdrainage has been installed.

DUAL CONCRETE PAVEMENT with stabilized dividing lane and wide shoulders exemplifies recent consideration in providing run-off zones for repair stops or to avoid collision.

One of the greatest handicaps placed on the maintenance man results from the designers' failure to provide subdrainage where soil surveys indicate it to be necessary. Even without investigation by soil specialists the designer should anticipate with reasonable accuracy the points along the road that require adequate subdrainage; this will be in most cuts, and certainly at the foot of cut slopes on sidehill location. The judicious location of surface intercepting ditches and subdrains on hillsides will frequently prevent bad slides; the former will also tend to prevent surface water from washing down over the cut faces and silting up the side ditches at the foot of cut slopes.

Another place where subdrainage treatment is usually necessary is just over the crest of a hill where the grade line has cut through the groundwater level, thus insuring seepage to the subgrade under the pavement. This softens the subgrade and causes the road surface to break up under loads during the spring thaw or during rainy seasons, especially a trouble with low-cost bituminous surfaces. Blind drains through these sections are a remedy, and obviously it is cheapest to place them in the original construction.

Bridges—An important problem of the maintenance engineer is to protect the footings of steel bridges and stringers at the abutments. Many bridge designs on unstabilized roads call simply for a flat-topped abutment and provide nothing to prevent embankment soil or road metal from flowing around the footings and the ends of stringers. Where fill material thus surrounds the steel, and especially where vegetation grows, rapid rusting is sure to follow. Many times maintenance engineers are shocked when they clean away this accumulation and discover dangerous weakening of the footings and stringers by rust—such hazard can largely be prevented by a design providing a step for the footings and a curtain wall extending up to the floor to keep the footings and stringers free from objectionable covering. This design also facilitates cleaning and painting.

Sodding Slopes—If the designer will call for sodded cut and fill slopes in the original contract he will help the maintenance engineer materially by preventing slope erosion and the filling of side ditches. Sodding also adds greatly to the attractiveness of the road.

Traffic service factors

Locating and designing engineers should provide for ample visibility; they should not make this the maintenance man's job. Frequently large sums of maintenance money are allocated to the improvement of visibility by widening cuts on the inside of curves, cutting down hills to provide longer vertical curves and similar operations which should have been thought out and provided for in the original plans and paid for out of construction funds.

Slipperiness — Much maintenance

money is spent on slippery road surfaces. A large part of this expense can be saved by the designing engineer. As an example; many states have now adopted the plan of transverse brooming of concrete surfaces as a final finishing operation thus slightly roughening the surface and reducing the danger of skidding. In brick pavements the application of whitewash-calcium-chloride or a similar agent to the brick surface before applying the bituminous joint filler makes possible the removal of excess bitumen from the pavement surface. Prior to this innovation, the maintenance man was frequently compelled to sprinkle coarse sand on the road to nullify the effects of the surplus bitumen. Excess bitumen in mixed-in-place bituminous surfaces usually causes fat spots and excessive bleeding during hot weather, which tends to produce a slippery surface and requires the application of stone or sand.

As to road types

Gravel—On secondary roads surfaced with unstabilized gravel, poor design and specifications may greatly increase the maintenance cost. The greatest fault is specifying a pebble size that, in spite of all the maintenance man may do, will result in a continually rough and bumpy surface. When oversize pebbles are used the road will never be in first-class condition, no matter how frequently it is dragged; when the large pebbles roll about on the surface they are a hazard to traffic, and when partly embedded they cause the automobile wheels to jump, which starts corrugation. No pebbles larger than $\frac{3}{4}$ in. should ever go into an unstabilized gravel road; better results will be secured if oversize pebbles are crushed to $\frac{3}{4}$ in., thus adding angular particles which compact under traffic and do not tend to roll around like marbles.

Another fault in gravel roads is the lack of sufficient binder for compaction. Originally clay was considered objectionable, but we know now that up to 10 per cent of clay is beneficial as a binder. A limited amount of sand is desirable so that the resulting aggregate will be well graded from coarse to fine, developing maximum density as nearly as possible. Crushing the oversize pebbles tends to increase the percentage of aggregate in the allowable upper sizes, thus permitting the use of more sand from the lower end of the size range. In this way less waste results both in coarse and fine material.

Crushed Stone — In traffic-bound crushed-stone roads it is the writer's belief that crusher-run stone with a maximum size of $\frac{3}{4}$ in. will give the best results under drag maintenance. Sufficient screenings and dust will be produced in the crushing to serve as binder for the coarser particles, and no matter how thin the road may wear no objectionable coarse stone will ever appear on the surface. In the past, designers have held the mistaken opinion that a stone road is never satisfactory unless it has a bottom layer of coarse stone. Specifications frequently permit the use of material up to a maximum size of 3 in. with a topping of finer aggregate including screenings, under the theory that this finer material will remain on top and form a smooth riding surface under proper maintenance. This is a fallacy, for two reasons: *First*, much of this finer material disappears down into the voids of the base course, and *second*, unless promptly replenished the fine material on top is sooner or later worn out and blown away or washed off, until the coarse base stone becomes exposed and is jerked out onto the surface by the maintenance equipment. Once this occurs, the maintenance man's attempts to produce a smooth road surface are hopeless.

Bituminous Surfaces—In stabilizing a gravel or stone road with bituminous material by the mixed-in-place method, many serious maintenance problems are introduced through poor design and specifications. Such construction usually calls for a light bituminous material as a primer to penetrate the base and nullify the effects of dust which may appear on the surface and throughout the aggregate used in the prime coat, but often the designer specifies too heavy a bituminous material, which hardens quickly and does not penetrate the base course.

Even a primer of the proper grade may give poor results if the seal coat is applied before the prime coat has had sufficient time to cure thoroughly and harden. Where the prime coat is sealed with a heavy bituminous material shortly after priming, waves or corrugations usually develop under traffic. Dig into one of these waves and the real difficulty is disclosed: the prime-coat material is found to be soft and unstable, permitting shoving under heavy loads. The heavy seal coat creates an airtight layer over the entire surface and prevents evaporation of the light constituents in the primer. The latter remains soft for weeks and months, with the inevitable "washboard" result. It is the writer's opinion that the primer coat should be exposed to traffic for at least four weeks before it is sealed.

In sealing the prime coat much raveling frequently results from specifying cover stone that is too large. The specifications for this cover stone may have wide percentage ranges on the different screens, which will cause considerable variation in the quantities of coarse and fine aggregate in the mixture, and often the cover stone ranges up to a maximum size of $\frac{1}{2}$ in. By the time this is transported and placed on the road the fine aggregate has sifted to the bottom and the coarse aggregate is exposed on the surface; the voids between the stones hold water, and when this water freezes in the fall or early winter it kicks the coarse pebbles loose and tends to ravel under traffic. Better results would be obtained if the fine and coarse aggregates were separated, the coarse to be applied first and coated with bituminous material, then the fine aggregate to be applied to filling the voids and remaining on the surface where it can adequately fulfill its function of sealing the surface.

In this procedure of course we run up against the divergence of opinion as to what causes slippery bituminous surfaces. One group maintains that we cannot secure non-skid surfaces without coarse aggregate; others maintain that, so long as excess of bitumen is avoided, we can secure an equally non-skid surface through the use of finer aggregate on top. The writer is inclined to agree with the latter opinion.

If bleeding results from the use of too much bitumen the resulting slipperiness can be corrected through the prompt application of fine-graded blotter stone. Much raveling is chargeable to insufficient bitumen to coat the aggregate and bind it in place. It seems preferable to err on the side of too much bitumen, as excess can be corrected by the addition of blotter stone, but it is difficult to correct the defects resulting from insufficient amount of bitumen.

Conclusion

The preceding outlines only the most important parts of road design wherein the designer can facilitate maintenance. The lack of coördination which exists in many highway departments would never be tolerated in a large industrial concern where the efficient functioning of each separate department must contribute its utmost in insuring a satisfactory, useful and economical product. In these days of diminishing budgets and increasing demands for highways service it is quite apparent that closer coördination of design and maintenance should be sought as a means of producing better roads and giving more efficient transport service.

Road Foundation Practice

Foundation practice has made great progress in recent years but is still in the trial stage; further advance awaits full quantitative knowledge of the behavior of soil under the action of loads and weather—Embankment construction already shows effect of new thinking.

CURRENT METHODS, *by* . . . T. E. STANTON, JR., *Materials and Research Engineer, California Dept. of Highways*
SHORTCOMINGS, *by* . . A. CASAGRANDE, *Director Soil Mechanics Laboratory, Harvard Graduate School of Engineering*

EDITOR'S INTRODUCTION

FOUNDATIONS were for a long time the neglected element of the highway. Now they are becoming subjects of somewhat extravagant attention. The swing of the pendulum is not farther than is perhaps needed but it is far enough to cast a shadow of danger that we are exceeding in practice our true knowledge of soils as foundation materials.

In the articles that follow, one by a practicing highway engineer and one by a research worker in the science of soil behavior are a statement of what is now being done in stabilizing foundations of soil and a statement of what we know and of what we still lack knowledge in respect to soils.

The outstanding and encouraging fact to be drawn from the two articles is that a way of anticipating soil action under pavement load and of controlling that action in some measure is spreading from the research laboratory into the practices of field construction. As a step in the rationalization of highway design, present activities, as outlined in the articles that follow, should be observed with closest attention.

Soil Surveys and Stabilization Control Practice . . . . . *T. E. Stanton, Jr.*

FOUNDATIONS have been going through a process of rapid development during the past decade, largely through the influence of the new science of soil mechanics. Because of the nature of the advance, however, the several elements of foundation practice are in different stages of progress. In each element, current practice represents a summation of trials and experiments.

Modern procedure in respect to road-foundation work is chiefly characterized by preliminary soil surveys, by extensive use of soil stabilization, by close attention to moisture control and drainage, and by greatly improved practice in fill solidification. The state of the art in these items is reviewed below.

Active study of soil problems is continuing. This is particularly true with respect to the underlying knowledge of soil properties and their change under various disturbing influences. Soil mechanics is the subject of intensive research by many different groups and institutions, and a statement of present road-foundation practice may properly begin with a word on this research activity.

Less than two decades have elapsed since the U. S. Bureau of Public Roads announced that it had begun investigations to obtain accurate scientific information regarding the characteristics of soils which affect their bearing value. At that time it pointed out that, if knowledge of road construction was to be advanced, first attention must be given to the road foundation and accurate information must be obtained of the properties of soils that make them good or poor soils for foundation purposes. The national agencies now engaged in soil and foundation engineering, in addition to the state highway departments and leading universities of the country, include the Highway Research Board, American Society for Testing Materials, American Association of State Highway Officials, American Society of Civil Engineers and Society for the Promotion of Engineering Education.

The Highway Research Board during 1936 perfected the organization of its new department of soils investigations. The first project committee appointed was on stabilized roads, and the work of this committee was divided among the members of five subcommittees. In the spring of 1936 the executive committee of the American Society for Testing Materials approved the extension of the society's activities by authorizing the formation of a major standing committee on soils for engineering purposes. In June 1936 the first International Conference on Soils and Foundation Engineering was held at Harvard University with delegates in attendance from all sections of the world. A new division of the American Society of Civil Engineers, to be known as the Soil Mechanics and Foundations Division, was formed during the year and the executive committee gave the personnel and an outline of activities approved by the board of directors at the 1936 fall meeting.

The leading state highway departments have expanded their organizations to include specialists in soil and foundation science and have modified their specifications for the construction of fills and pavement subgrades to insure foundations adequate for all probable traffic demands. Some states have gone further than others, but all state highway departments are organizing and equipping bureaus to exercise whatever measure of investigation, test and control is demanded by local conditions. Taking the country as a whole, current practice covers the entire field of soil mechanics even though no one state highway department may find it necessary or economical to include all phases of the subject.

WIDENING OF ROADS introduces the chance of surface failure unless care is exercised in obtaining uniform foundation conditions for the widened roadway.

Few states now neglect making soil surveys in advance of construction; many have extensive soil-survey and testing organizations. While the current practice is to follow the Bureau of Public Roads system of soil identification and classification, which is based on plasticity, moisture equivalent, grain size, shrinkage and swell determinations, modified somewhat by local conditions and requirements, including at times laboratory and field bearing value tests, there is growing realization of a need for common symbols and definitions; methods of exploring, surveying and sampling soils for highway purposes; methods of testing and classifying disturbed soils; methods of testing soils in place; and in general standardized procedure for solving all of the related problems of soil mechanics.

Stabilization widely practiced

Current practice almost universally calls for the removal of unsuitable subbase material and its replacement with suitable material, or else blanketing an inferior subgrade with varying thicknesses of selected material depending on the exact nature of the foundation material, the type of pavement surface and the nature and volume of traffic. But while it is undoubtedly current practice to import suitable natural materials either to be mixed with unsuitable local soils or to be used as replacement, there is an increasing tendency towards other methods of stabilization where suitable selected materials are not readily available. The particular type of soil stabilization in favor depends to a large extent on geographical location. Treatment with calcium chloride has made rapid strides in the east; bituminous emulsions are used in the west, and bitumen in some form is probably more generally used throughout the nation than any other stabilizer. Probably in no phase of soil mechanics does current practice vary so widely as in stabilization. Extensive studies are under way to develop methods and materials.

While the necessity of adequate drainage is universally recognized, the importance of uniformity in moisture control has not been sufficiently appreciated in most states to call for any special construction practices other than to recognize, in principle, the necessity of adequate subgrade drainage as well as water-course drainage. And even this general principle is all too often overlooked in actual construction, with the result that extensive fill settlements and slipouts occur on heavy grading jobs. Without doubt, however, the trend is towards more thorough subgrade and foundation drainage.

In current practice corrective measures against destructive frost action consist essentially of constructing granular well-drained base courses and watertight surfaces, with an attempt to secure watertight joints where artificial cracks or joints are constructed to relieve volume-change stresses. Common practice in repairing frost boils or heaves consists in excavating the offending base material to depths of 2, 3 and even 5 ft. and replacing it with granular well-drained material. Drainage, pervious subgrade material and watertight surfaces are deemed the most essential preventive measures against frost action.

Fill solidification

Up to seven or eight years ago it was common practice to build fills by end dumping or in layers of 12 in. or more and to effect solidification (if at all) by requiring the scrapers to travel evenly over the surfaces. No particular effort was made to ascertain the exact degree of consolidation during construction or the probable future settlement. Under this haphazard procedure fill settlement usually continues over a period of years, and any pavement surface constructed on fill is doomed to early failure.

In 1929, the California Division of Highways made extensive investigations to determine the optimum moisture content and construction procedure

IMPROVEMENTS IN EQUIPMENT have done much to facilitate the proper placing and compaction of soils in building highway fills

for the consolidation of fills to insure against subsequent settlement. From this study methods of testing were developed for optimum moisture and consolidation. This resulted in a modification of the California standard specifications in 1929 to require that embankments should be constructed in layers not exceeding 8 in. thick; that each layer be thoroughly compacted with a 12-ton three-wheeled power roller or with a tamping (sheepsfoot) roller of specified design; that unless the material when placed in the fill is moist enough to be properly compacted, each layer must be watered sufficiently to dampen the material before it is rolled and that new layers must not be constructed until the layer under construction has been thoroughly compacted. Soil samples from the fill are taken continuously during construction to determine density in comparison with a laboratory specimen of the same soil fabricated to maximum density with optimum moisture content.

As a result of the work in California and in other states, dating back at least to 1929, it is now common practice in the majority of states to require that fills be constructed in 6- to 8-in. layers properly watered and compacted with heavy three-wheel or tamping rollers. Some of the larger roadbuilding states still permit fills to be constructed in 12-, 18- and even 24-in. layers without adequate provision for wetting and compacting unless a hard-surface pavement is to be constructed immediately; in the latter case greater precaution is usually taken to secure immediate maximum consolidation. Without doubt, however, current practice gives more care to consolidating embankments than previous practice, and the trend is towards a general adoption of specifications requiring that fills be constructed in shallow lifts with moistening and thorough compaction.

Measures of Soil Behavior Are Still Imperfect

.....A. Casagrande

THE DESIGN of pavement foundations for high-type roads offers most difficult problem in applied soil mechanics; in spite of strenuous efforts at solution during the past ten years relatively little progress has been made. This fact, coupled with the divergence of opinion on the many intricate problems which are involved in the mechanics of pavement foundations, makes it a thankless task to appraise present practice.

The design of a road requires knowledge of all pertinent properties of the pavement and of the underlying materials to a considerable depth. In addition it is necessary first to know the factors that influence these properties and the range of possible variations; second, to know all factors which introduce stresses into the pavement and the foundation, the magnitude of these stresses and their possible combinations, and finally to have sufficient command of analytical methods to permit the study of the stress-strain relationships in the combined body to pavement and foundation strata.

During the past ten years simplified approaches have been undertaken to this problem of determining the stresses in the pavement and of the rational design of the foundation. The writer considers the following three of importance:

1. Empirical studies of the relation between pavement and foundation based on comparisons of the behavior of pavements, the constants of the underlying soil being determined by simple tests on disturbed samples.

2. Theoretical analysis of the stresses in a concrete pavement based on simplifying assumptions of soil reaction.

3. Direct measurement of the deformations and stresses in pavements, under foundation conditions as nearly uniform as possible.

The results of all these investigations have been very helpful to highway engineers; if not quantitative, at least qualitative conclusions can be derived, which make possible (within limits) a balanced pavement design where good foundations are available. Withal, however, the variation in foundation soils and their characteristics is so great that a general approach to the problem of designing a pavemnet and base course to fit the actual soil conditions is still remote.

Influencing soil porperties

In the writer's opinion a satisfactory solution can be obtained only by combining thorough observations of the behavior of pavements with actual measurements of the pertinent properties of the underlying soil and their changes due to climatic conditions. Experience in recent years has definitely established that, with very few exceptions, knowledge of these properties cannot be derived from routine tests on disturbed samples. The most important function of future research will consist of taking and testing undisturbed samples from various depths beneath the center and the edges of the pavement at such times as to permit study of extreme seasonal variations.

Problems in earthwork and foundation engineering may be divided roughly into two groups: (1) Those in which we are primarily interested in safety against failure due to rupture or plastic flow of a mass of soil, and (2) those in which our interest is in the volume changes and deformation of the soil. Correspondingly soil properties fall into two groups: those which determine the resistance of the soil to failure, and those which govern changes of the soil within a range of stress which is safe from failure.

In the first group belong all problems relating to safety against slides in natural slopes, slides within embankments or through their foundations, radical changes in the strength of soils caused by freezing and thawing or other influences. Naturally, safety of the foundation against failure is a very important consideration in highway engineering. The principal soil properties governing this group of problems are: the shearing resistance of the soil; the coefficient of permeability; a constant describing the difference in consistency between the undisturbed and remolded states, which indicates the degree to which progressive failure will take place; and the extent of stratification and fissures, which influence the creation of hydrostatic pressure and may cause slides.

In the second group belong all problems dealing with the normal changes that soil undergoes under superimposed static and dynamic loads and under the influence of climatic variations. To analyze these changes it is necessary to study the stress-strain relationships of the soil by means of confined and unconfined compression tests on undisturbed samples under various possible conditions, supplemented, if necessary, by special loading tests in the field.

In addition to the stress-strain relationships under static loading, which we are able to determine by means of modern soil-testing methods, there are other factors which should be taken into consideration, particularly the effect of dynamic loads on the structure of undisturbed clays.

What has been said is not intended to convey the impression that the ordinary routine soil tests commonly used today need not be performed. On the contrary, the use of these tests should be continued until specialized knowledge resulting from extensive studies permits reliable conclusions as to the usefulness and meaning of such tests in the design of pavements.

HIGH FILLS now are built up in compacted layers instead of by end dumping. This practice eliminates the uncertainty of settlement and makes it safe to lay pavements on new fills.

Summarizing the foregoing discussion in the accompanying table, it becomes apparent that the progress of our knowledge during recent years chiefly covers the prevention of foundation failures. In the following sections some of the present trends and advances will be discussed more in detail.

Embankment design

Embankments should be designed and constructed so that they will be safe against failure due to slides and so that large enough differential settlements will not occur to harm the pavement or to produce an undesirable riding surface. The source of possible trouble may reside in the ground on which the fill is placed or it may reside within the fill itself.

It is not possible to give definite figures of the magnitude of total and differential settlements which can be permitted. Ten years ago the idea prevailed that the most economical procedure was to place a temporary pavement on fills which were expected to settle, and to wait for about a year (or less) before placing the permanent pavement. More recently engineers have favored building fills in such a way that a high-type pavement may be placed immediately. One of the reasons for this change is that poorly-constructed fills often necessitate much pavement maintenance, because differential settlement takes place not only during the first year but for many years afterward.

Preparation for the fill

The present tendency is toward elimination of very soft layers of substantial thickness beneath fills, even if a stability analysis establishes a sufficient safety factor against foundation failure. Only when such layers are uniformly thin is it permissible to build a fill upon them. However, each case must be analyzed before a decision can be made, since settlement is influenced by height of fill, by character of the soil of which it is built, by methods of construction, and finally by the type of road and pavement. For example, a sandy or gravelly fill of substantial height can smooth out so effectively the settlements resulting from the compression of soft underlying strata of varying thickness that a total settlement of several inches may be tolerated even where the pavement is of high type. On the other hand thin lenses of such material beneath a low clay embankment may result in harmful differential settlement, while the total settlement may not appear to be of a dangerous character. The time required for consolidation of soft layers is important whenever it is intended to allow consolidation before placing the permanent pavement.

On the basis of an accurate soil profile and consolidation tests on typical undisturbed samples of the compressible strata it is not difficult to determine the character and time-progress of the settlement and then to arrive at a satisfactory solution in each case. In this connection one should keep in mind that the relatively pervious organic soils, in which primary compression takes place within a short time, exhibit a secondary effect that will cause progressive settlement for years after the primary time effect has ended.

Whenever an embankment is built up of plastic soils, special attention should be paid to gradual compression of the fill material. This compression can be accelerated by introducing a few horizontal layers of sandy or gravelly soil. These layers provide at the same time a very desirable increase in stability of the mass against plastic lateral deformation and slides. Special care is required in the construction of

BEHAVIOR OF PAVEMENT FOUNDATIONS

Foundation Failure	Normal Behavior of Foundations
Examples: Slides in natural slopes or in embankments; subsidence of fills due to slides or plastic flow in subsoil; complete loss of strength of foundation due to rapid thawing of soils containing large amounts of excess water stored up in form of ice; etc.	Deformation and volume changes caused by traffic loads, warping of pavement, the effects of seasonal variations; differentiation between seasonal variations and permanent changes, gradual settling of embankments due to consolidation of fill material or of underlying soft strata, etc.
Application to pavement and foundation design No direct bearing on pavement design. Soil mechanics permits fairly satisfactory stability analysis of most problems encountered in highway engineering. Excessive frost penetration into subgrade can be prevented by appropriate base course design; possibilities of heat insulation not sufficiently explored.	The basic problem, stress analysis in pavement, base course and subgrade in their true relation, not yet solved. Knowledge on pertinent subgrade properties and their gradual changes entirely unsatisfactory. Empirical knowledge available on effects of differential settlements on concrete pavements and on how to overcome them with dummy joints; special design of pavement sections joining abutments and fill; etc. Transverse joints particularly sensitive on clay subgrade with insufficient base course. At present excessive flexibility of subgrade, discontinuities, frost action, etc. best counteracted by ample thickness of base course. Drainage in some soils very important, in others useless. Subgrade treatment effective only to a very limited extent. Compaction control for all construction.

such layers to prevent the formation of water pockets. The surface on which each layer is placed should be finished so as to slope down from the center line of the embankment.

Stability against slides

Analysis of stability against slides within an embankment or through its foundation, is best carried out by the Swedish method of cylindrical sliding surfaces. The shearing resistance of typical samples can be determined by direct shearing tests, unconfined compression tests and squeeze tests. While there are still questions on a number of important points, particularly regarding the testing of the shearing resistance of cohesive soils and the factor of safety which should be used in the stability analysis, experience has indicated that the Swedish method is the most reliable now available. Extensive application to actual slides in European countries and a few examples of application to slides in the United States have shown a factor of safety of about 1 or slightly smaller then 1.

Our knowledge, then, has developed to a point where slides in embankments and in the underlying foundations can be foretold and prevented by appropriate design. Such analysis requires, first of all, accurate exploration of the substrata. It is in this respect that most foundation work is still badly lacking. The cost of borings and soil tests are insignificant in comparison to the costly repair work resulting from foundation failures, and yet negligence seems to be the rule rather than the exception, a situation which is difficult to understand.

Compaction of embankments

It is gratifying to notice that the importance of proper compaction of embankments is being increasingly realized. Only a few years ago embankments were built by dumping the soil, with only the most meager compaction under the wheels of operating trucks and graders. Today many highway departments require in their specifications detailed methods of compaction. The thickness of the individual layers is limited and the method of compacting each layer is specified.

In some states where sandy and gravelly soils are predominant and are readily available for the construction of embankments, a satisfactory degree of compaction seems to be obtained by placing the soil in relatively thin layers and rolling each layer thoroughly by the heavy bulldozers which are used for spreading the soil. In a few states, where cohesive soils predominate, sheepsfoot rollers are beginning to be used to great advantage and specifications for the control of compaction embody the experience gained during recent years in the construction of rolled earth dams. The extensive experience which is being accumulated should lead in the near future to satisfactory standards for compacting cohesive soils based on relatively simple soil tests.

Sandy soils needs study

In this connection it is interesting to find that while good progress is being made in the United States in methods of constructing embankments of cohesive soils, almost no studies have been carried out on the stability of embankments constructed of sandy and gravelly soils. It is true that in the majority of cases such soils will not cause as much trouble in embankments as will cohesive soils, but certain cohesionless soils, particularly fine sandy soils, have in their loose state a rather sensitive structure. Saturation by a heavy rain storm may cause serious sudden subsidences, and continuous vibrations (traffic) may produce gradual settlement, often irregular, and harmful to the pavement.

Extensive studies of the efficiency of various methods of compacting cohesionless or slightly cohesive soils have been conducted in Germany in connection with the construction of the system of superhighways. They seem to indicate that the most efficient method consists of introducing vibrations into the soil, and preferably keeping the soil saturated to prevent the formation of internal capillary stresses, which tend to counteract the compacting effect of vibration. On account of the expense of the heavy vibrating machines, contractors prefer the use of tamping equipment. Several of these machines were described in *Engineering News-Record*, July 23, 1936. Other methods investigated, such as sluicing, ponding and ordinary rolling with various types of rollers, were found to be much less effective.

Summarizing, it can be seen that the tendency toward construction of embankments which will settle as uniformly and as little as possible is quite pronounced in many states as well as abroad. Today, most engineers agree that the added cost for compaction is more than offset by the better riding surface obtained and by reduction in maintenance cost of pavement, shoulders, guard rails, and other elements of the road structure.

Discontinuity in foundations

Next in importance to safety against failure is provision for as gradual a transition as possible between sections of pavement whose foundation conditions differ. In most cases common sense dictates the necessary precautionary measures, yet apparently for the sake of speed in construction the simplest expedients are often omitted. Important examples of places where trouble is encountered are: Sudden transition from fill to cut or from a bridge abutment to the adjacent embankment; sudden changes in subgrade, particularly where clean sand or gravel meets a silty soil or clay and, finally culverts—the most frequent offenders.

The writer has regularly observed during the past eight years a concrete pavement which over the greater portion of its length heaves fairly uniformly up to 7 in. every winter without damage and without impairing the riding qualities. Only in one short stretch, where irregular heaving of not more than an inch or two occurs, has the pavement cracked badly. Today it is possible, on new construction to recognize the sections in which soil condi-

tions change rapidly, and to design the foundation accordingly. Usually a substantial base course of soil which does not cause ice segregation is introduced, either by lifting the grade or by excavating deeper into the poor soils. When the excavation is carried deeper, a gradual transition over a distance of at least 25 ft. is required to prevent the formation of irregularities in the surface. The same requirements should govern the design of the base course

WIDE FLUSH CURBS now are required for bituminous or brick surfaces on concrete bases to prevent side spreading and provide edge traffic markers; the curbs shown are integral with the base and 12 in. wide.

adjacent to culverts; it should be gradually increased in thickness toward the culvert, at which point it should be sufficient to prevent normal frost penetration.

Even today one can find on new highways of principal importance bridge abutments which throw passengers from their seats when crossed at ordinary travel speed. Transition slabs of special design, at least 30 ft. long, resting with one end on the abutment and with the other on the fill, are required; it would be uneconomical and often impossible to make the adjustment in the foundation.

Provision for deformation

On modern high-speed roads all transitions must be so designed that deformations of the road surface such as are found today on practically every road are prevented. If this is done, no special measures are required in the construction of flexible types of pavements, while in concrete pavements some additional flexibility can be introduced by dummy joints. It is particularly important that a joint should be placed at the center line of each culvert, and dummy joints on both sides at distances of about 10 ft. Provisions for mudjacking should be made where differential settlements are anticipated and are not properly taken care of in the design.

Conclusion

The foregoing observations lead to the conclusion that highway foundation design is still in a rudimentary stage and that its future is dependent on extensive research, which can only be undertaken by highway engineers and in cooperation with specialists in soil mechanics.

The most serious handicap to progress at present resides in the fact that the number of highway engineers who are also thoroughly trained in modern soil mechanics is far too small to permit undertaking such a research program. In addition, it is to be regretted that the soil specialists working with highway departments received so little encouragement and are given so little time to inform themselves of the rapid progress in this field by yearly inspection of similar work by other highway organizations and of the research in progress at the leading soil-mechanics laboratories. Soil mechanics in its present stage of development can be more a liability than an asset to an engineer unless he has the initiative and opportunity to keep abreast of the latest developments by personal contact.

Executive highway engineers may be loath to give financial support and encouragement to work which may require many years before practical results are obtained. Is it necessary to remind them that a cheap pavement on a good foundation will make a better road than a good pavement on a poorly-designed foundation? Is it necessary to recall that many pavement failures found on the highways built under their direction are really foundation failures? It is necessary to remind them of the great importance of foundation studies to economical and safe location or relocation of roads?

Particularly in connection with location studies of superhighways with their expensive fills, cuts and structures the location of which can be chosen within a wide latitude, a staff of highway engineers thoroughly trained in soil mechanics and familiar with the soil types of that particular region can be of inestimable value. And let this reminder be followed by the suggestion that in selecting new men for soil work, not only for advancing our knowledge but also for a satisfactory application of what we know today, the best men will be barely good enough.

Substantial progress in the field of pavement and foundation design is not possible until we have a clear and quantitative knowledge of the normal behavior of the principal types of soil under pavement loads and weather influences. Not until this gap in our understanding of the mechanics of subgrades is closed will it be possible to derive the full benefit from the extensive and valuable studies on pavement design which now are available.

It is not the purpose here to propose an outline or detailed suggestions for the research which is needed. That can be done only on the basis of extensive preliminary work. However, a warning is offered, a lesson learned from the past. Frequently long stretches of a road have been subjected to soil surveys in which only one or another single factor is observed, a factor which happens to be of special interest or is suspected to be the cause of a certain behavior of the pavement. A later analysis of such records indicates only too often that a number of factors were not observed, which during the study are found to be essential. In many cases such observations are simply a waste of money. The only correct method of investigation is to choose carefully a limited number of cross sections or short stretches of the road on which all factors which may possibly have an influence on the problem are carefully observed.

Thus, frost-heaving observations over many miles of road without observing any other data or with only very meager information on the subsoil are practically without value. Only in combination with accurate observations on groundwater fluctuations, the character of ice segregation and depth of frost penetration, the determination of grain-size distribution, and other classification tests on typical soil samples and meteorological data, can such a study be of value. A small but thorough program may lead to valuable results, while a very extensive program comprising the entire highway system of a state, with superficial observation, is usually without value.

Surfaces Still a Problem

Practice follows quite steadfastly certain usages that have been evolved from research and trial, but experience indicates that a review and revision of details and a new sense of pavement design values are called for before they will be accepted very generally

CURRENT DESIGN *summarized by* . . . R. D. BROWN, *Principal Highway Engineer, Bureau of Public Roads*
CHANGED THINKING *urged by* . . . . J. S. CRANDELL, *Professor of Highway Engineering, University of Illinois*

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EDITOR'S INTRODUCTION

UNTIL RECENTLY design thinking has not extended much beyond the problems of superstructure—the paved or surfaced way on which the vehicles travel. It is now reaching farther into problems of foundation support and off-pavement roadway shape and dimensions. But surfacing is still of vital concern and particularly surfacing of the rigid type—its design problems are not yet solved.

The first surfaces were merely floors or carpets laid on the ground and they failed generally. There began a period of trial and error, a study of vehicle loads and of temperature and moisture stresses, intricate mathematical analysis and vast experimentation and from all of them types and designs of surfaces described in the first of the following articles have been evolved. The advance is remarkable and in instances has almost reached perfection, but design and construction have still a long journey ahead before road surfacing receives respect as satisfactory engineering. The second article indicates how far engineers have to go to improve the design of surfaces.

Pavement Design Has Evolved From Practice

R. D. Brown

AS THE DICTIONARY defines "standard" there are no standards of design for pavements. At best we have preponderance of usage, and the only dictator in this connection is the body of knowledge built up through research and experience. The following statement of present usage in rural highway paving is purely factual.

Width and crown

Basic to all design is width and crown. Assuming proper alignment, grades, sight distance, adequate shoulders and a pavement surface suitable for modern traffic speeds, a two-lane pavement will serve about 4,000 vehicles a day quite efficiently. The standard width of such a pavement is 20 ft., but 18-ft. widths are still common where traffic is not expected to exceed 750 to 1,000 vehicles a day. There is a definite trend toward a 22-ft. pavement for the more heavily traveled roads, particularly where there is a considerable percentage of heavy trucks and buses.

On highways requiring more than two traffic lanes the increased width is obtained by adding 10-ft. lanes in pairs. Traffic in opposite directions on multiple-lane highways is preferably separated by a center parking strip not less than 40 ft. wide, and where this is not feasible traffic separation is obtained by constructing a surfaced median or neutral strip of contrasting color, preferably raised slightly and from 3 to 6 ft. wide. The three-lane pavement for two-way traffic is a compromise dictated by the necessity of providing some traffic relief and the lack of funds to provide four-lane construction.

A 1-in. parabolic crown is standard for two-lane pavements and all dustless surfacings. In multiple-lane construction the rate of crown is increased progressively from the inner to the outer lanes, to a maximum of 1½ or 2 in. per lane for three adjacent lanes. Very few highways are constructed with more than three adjacent lanes for traffic in one direction.

Brick pavement

The current standard design for new brick pavements includes a 6-in. concrete base, ¾-in. bituminous mastic cushion and 3-in. de-aired vertical-fiber lug brick with asphalt joint filler. The concrete base is designed for a tensile strength of about 500 lb. per sq.in. in 14 days. Header curbs of richer mix, 6 to 12 in. wide, are constructed monolithically with the base. The same surface trueness of base is required for concrete pavement is essential because of the thin cushion used. A 5-in. base is used to some extent where few heavy trucks are expected, and up to 8-in. base is common where large numbers of heavy trucks are to be carried.

No joints, other than necessary construction joints, are ordinarily used in the base. The standard mastic cushion contains 7 per cent of asphalt by volume and is carefully placed to true contour. Although 3-in. brick represents prevailing practice, 2½-in. brick is used for predominantly light traffic and 3½-in. brick where a large volume of heavy traffic is expected. Asphalt mastic filler is used to some extent, but the more common practice is to use an asphalt filler of 30-40 penetration. Excess filler is removed from the surface of the pavement to provide a clean, non-skid surface. This is accomplished by coating the surface of the brick with whitewash or calcium chloride to permit the excess filler to be peeled off with a sharp, cutting tool.

Concrete pavement

Principles developed by tests, by observation of action in actual service and by abstract analysis are now generally applied in the design of concrete pavement. Experience and research show that in a balanced design the center thickness should be two-thirds of the edge thickness.

A NEW EXPERIMENT in stabilization is making dirt shoulders travelable by bitumen-impregnated cotton cloth covered with stone chips.

The standard design for two-lane construction is 20 to 22 ft. wide, 8 in. thick at the outer edge and 6 in. thick in the central portion; the increase at the edges is obtained in the outer 2 or 3 ft. In constructing three or more adjacent lanes the inner lanes are commonly of uniform thickness. Where the traffic includes many vehicles whose wheel loads approach the legal maximum a section 10 in. thick at the edges and 7 in. in the center is used. Where subgrades have high and uniform bearing power, heavy vehicles are not too frequent and severe frost action is not anticipated, a reduction in section to 8-5½-8 in. or to a maximum of 7-5-7 in. is employed to reduce cost.

Joints—To control longitudinal cracking, construction joints separating traffic lanes are standard. In full-width construction the joint is formed by a metal plate shaped to provide a tongue and groove or by an indentation forming a plane of weakness. In lane-at-a-time construction the joint is either a plain butt joint or a tongue-and-groove joint formed by a shaped metal plate or a timber attached to the side form. To provide for load transfer, to eliminate the necessity for thickening the inner edges and to prevent the joint from opening, deformed tie bars 1½ in. in diameter, 4 ft. long, spaced 5 ft. c. to c., are commonly specified.

Transverse expansion joint design has not been standardized, but invention is actively engaged in developing an ideal point that will provide for (1) expansion and contraction, (2) load transfer, (3) a watertight seal, and (4) continuous and efficient service throughout the life of the pavement.

Poured and premolded bituminous fillers, which are extruded as the pavement expands, are being largely replaced by premolded compounds of mineral or vegetable matter. Air-chamber joints of various designs now on the market are being used to a considerable extent in some states. Expansion joints are placed perpendicular to the center line, not more than 100 ft. apart, and provide openings not less than ¾ in. nor greater than 1 in. Provision is made for load transfer across the joint by dowel bars or other appropriate devices; the standard dowel-bar construction is ¾-in. plain round bars 24 in. long spaced 12 to 15 in. c. to c.; one end of each bar is treated to break bond and provided with a metal sleeve cap to permit movement in the slab. A number of special load-transfer devices are available that because of special design, are more efficient than ordinary dowels; these are used at spacing up to 20 in.

Contraction joints are a means of transverse crack control. Except where steel reinforcement is used for this purpose, suitably designed transverse contraction joints are so spaced that the distance between joints (including expansion joints, does not exceed 30 ft. The contraction joint is either an impressed plane of weakness or a shaped metal plate, and is provided with dowels for load transfer the same as are expansion joints.

Reinforcement—Steel reinforcement is not employed to strengthen the pavement structurally and is not placed in the slab at a depth to serve this purpose effectively; the primary purpose is to prevent or reduce cracking and, when cracks do form, to prevent them from opening. To accomplish this the reinforcement is used in the form of wire mesh or bar grids composed of small bars closely-spaced to secure uniform distribution of the steel throughout the slab. By reducing subgrade drag by the use of short slabs, a balance is obtained between the cost of steel reinforcement and the cost of expansion and contraction joints. In slabs less than 30 ft. long reinforcing is not ordinarily employed except where severe frost or poor subgrade support indicate its use to be desirable as a precautionary measure. In longer slabs and under ordinary conditions not more than 40 to 50 lb. of reinforcing steel per square (10x10 ft.) is ordinarily used.

Bituminous pavements

Bituminous surfacings range from high to low type, including light surfacing and dust-palliative treatments; types lower than bituminous macadam are not considered here.

Bituminous pavements are classed as rigid or flexible, according to the type of base upon which they are laid. The

higher types, such as sheet asphalt, bituminous concrete (either hot or cold-laid) and rock asphalt, are commonly (but by no means exclusively) constructed on a concrete base with integral header curbs 6 to 12 in. wide and are considered rigid pavements. Concrete base construction for rigid bituminous pavements is substantially the same as for brick pavements.

High-type bituminous pavements are sometimes laid on flexible bases, particularly where advantage can be taken of existing macadam or other surfaces that have considerable residual value because of compaction under traffic but are inadequate for present traffic volume and speed because they lack adequate width or depth, have excessive crown or are rough.

Bituminous Concrete—Sheet-asphalt and dense-graded bituminous-concrete surfaces are laid on binder courses, the total compacted depth of top and binder course varying from 2 to 2½ in. The depth of binder course varies from 1 to 2 in. and the depth of top from ¾ to 1½ in. Coarse-aggregate bituminous-concrete pavements vary in depth from 2 to 2½ in. and are laid without a binder course. Rock asphalt on original construction is usually laid in a single course to a compacted depth of 1 to 1½ in. Rock asphalt provides a natural non-skid surface texture; standard practice calls for a non-skid texture also on sheet asphalt and bituminous concrete surfaces. Machine spreading and finishing to insure true riding surfaces are standard practice.

These requirements also hold when bituminous surfaces are laid on a new or a reconstructed flexible base. In their design particular attention is given to the bearing power of the subgrade; the pavement thickness is determined for the most adverse subgrade conditions, which will ordinarily exist during the spring when subgrade moisture is at a maximum. Economy in design depends upon a proper balance between (1) expenditures for subgrade drainage and stabilization, and (2) depth of pavement. A major research project of the Bureau of Public Roads is directed toward establishing a basis for the rational solution of this problem.

New flexible-base construction for high-type surfaces ordinarily consists of 8 in. of compacted gravel or macadam laid in two courses and preferably exposed to traffic for a few months before the top is placed. Separate header curbs are sometimes constructed, but the more common practice is to extend the base about 12 in. beyond the edges of the top course to give edge support. When a bituminous base course is used the total depth of base is reduced somewhat, and in all cases due allowance is made for granular material or road metal already in place. The total depth of high-type bituminous surfaces and flexible base varies from 6 or 7 in. to 12 in. or more depending on subgrade conditions. The principle of stage or phase construction is applicable to all types of bituminous construction on flexible base.

Bituminous Macadam—True penetration macadam was developed in the northeastern states, and its use is largely confined to them. It is constructed to a depth of 2½ to 3 in. using trap rock or other dense, hard aggregate, and is usually laid on a water-bound macadam base 4 to 5 in. deep. A gravel or fieldstone sub-base ranging from 4 to 12 in. or more in depth is used for heavy-traffic routes and to compensate for poor subgrade and severe frost action.

Curbs used on rural highways are confined almost entirely (1) to the lip curb used on grades in excess of 1 per cent in areas where the soil is particularly subject to erosion and (2) to a sloping curb to outline raised center parking areas, traffic islands, and other restricted zones.

Lip curbs are constructed integrally with the pavement and are generally used only on concrete pavements. They are from 2 to 3 in. high at the outer edge and from 8 to 12 in. wide, forming a shallow gutter at the edge of the pavement but permitting vehicles to pass over them without difficulty. Paved flumes are provided at suitable intervals to carry the surface water to the roadside. Sloping curbs to outline raised center parking areas or traffic islands have a sloping face of 45 deg. or flatter and are from 3 to 4 in. high.

A New Sense of Design Values Is Needed

J. S. Crandell

THE EARTH ROAD has always been with us, and not much has been done until recently to improve it. In fact, instead of trying to better it the idea seems to have been to supplant it. Gravel was one of the materials that was first experimented with; Rome tried it, and built hundreds of miles of gravel ways, but as these were not wholly satisfactory broken stone was later tried. Broken-stone roads need to be compacted with a heavy roller, and there was none to be had; also, some sort of binder is necessary to hold the stone particles in place. In Mesopotamia asphalt was used; in Rome puzzolana cement was found to be suitable, and the concrete road was invented. Of course, it must be remembered that stone-slab, brick and bituminous pavements had made their appearance elsewhere as many as 2,000 years before Roman roadbuilding began, but their history is not so well preserved.

Why this excursion into antiquity? Because if we look back through the centuries we find that in roadbuilding we are not far ahead of Julius Caesar's day and age. We are using the same materials for the same purposes and the results will be similar.

However, we do have a new means of locomotion on our highways, and whether or not we like it we are going to see this locomotion increase in speed. Our highways then must be built or rebuilt to accommodate very fast traffic. Our highway situation is that which the railroads faced forty years ago: They stopped building new mileage to improve what they already had—they constructed new bridges, doubletracked lines, removed grades and curves that interfered with speed and safety, introduced automatic signal systems, began the removal of dangerous grade crossings and gradually but surely modernized their lines. Their motive power has always been years ahead of their roadbed, just as is the case with our highways.

Messy concrete thinking

The same basic track defect is common to both railway and highway—the *joint*. Despite the hundreds of inventions that the mind of man has evolved for rail joints a wholly satisfactory one has never been devised. And similarly the joints in concrete pavements and bases are the weakest element in road design. No one has developed a perfect joint; if you think otherwise you have but to look at or ride over existing pavements. Here lies the opportunity for a great improvement in the rigid pavement.

The designer must remember that the term "rigid" is comparative. Actually a concrete pavement is constantly in motion, for it is expanding, or contracting, or warping, or twisting, or being pushed out of place by traffic or the elements. Sunshine and shade, snow and rain, wind and weather, all have their effect on the so-called rigid pavement.

The engineering world has gone mad on the mathematical design of concrete slabs, and meanwhile faulty joints have proceeded to destroy these theoretically well-designed slabs once they are in place. Why not take a day off, forget bending moments and balanced sections, and, escaping from our moments of inertia, really evolve the perfect joint?

Let us not fool ourselves about the pre-eminence of concrete, but it is such a worthwhile product that it is a shame to see it so badly used and abused by its friends and its enemies. The design of concrete pavement has been worked over

and over and over again by a vast number of persons. Frank T. Sheets has done an excellent job in codifying much of this work, relieving it of its higher mathematics and bringing it down to earth, in his booklet issued by the Portland Cement Association under the title of "Concrete Road Design."

Everyone knows that concrete cracks. Everyone who has observed the material knows that frequently when it is laid in highway slabs it cracks into pieces that are less than 15 x 15 ft. These pieces may crack again and yet again, until they approach what has been said to be the size best suited to highway work, namely, 4 x 4 ft.

Now, we are aware of this characteristic, but we have not sought to make use of it. We have pretended that it does not exist. All materials have their defects, and cracking is the worst defect that concrete is heir to. No matter how well a concrete slab is made, slabs five or more years old would reveal that concrete tends to crack. Knowing this, let us design accordingly!

We may and must invent a joint that will take care of expansion, contraction and warping, be waterproof, transfer loads, be cheap and give no cause for complaint of any kind the year round. With such a joint we will lay concrete pavements in small slabs that will not crack and our pavement will be good for many, many years.

Recently, vibrated concrete has been exploited. It is not new, but it has advantages that ought to be looked into. A denser concrete is produced and the slabs are stronger; the excess water and fines are brought to the top where they may be removed, or fresh aggregate (perhaps with extra cement) may be added and vibrated into the wearing surface. Again, a somewhat leaner mix may be used with well-vibrated

ADVANCED DESIGN contemplates stabilization of gravel and soil road surfaces using bitumens, cement, lignum, deliquescent salts and other binding media; the view shows gravel stabilized with sodium chloride.

if it is at all sizable it will and it must crack, for the very material that binds it together is the same that causes the mass to shrink and tear itself asunder. And still we go on ignoring this simple, well-established and ever recurrent fault. The blame is not that of the manufacturer, the salesman, the jobber, the contractor, the inspector, the taxpayer or the politician; it lies heavily and solely on the civil engineer.

We have formulas without end, as to thickness of slabs, thickened edges, reinforcement, joints, dowels, hinges along the center line, until the reader is lulled into the belief that these imposing mathematical demonstrations will surely result in the production of the perfect pavement. Alas! They are all based on the design of the conventional slab. The interesting fact which any concrete road or base would tell the designer he apparently never learns. An examination of concrete concrete. It is true with concrete as with cabinet work that the amount of binding medium should be the least possible: too much cement is as disastrous as too much glue. The vibrator serves the same purpose with concrete that the handscrews do in carpentry; the excess binder is forced out and the body-building particles are brought close together. We need to consider vibrated concrete.

The Fedi vibrator and finishing machine have produced some remarkably excellent results in Paris. A dry and very lean mix has been placed in some of the business streets, and the resulting pavements have stood up well. After eleven years of service the surface is free from objectionable cracks, and still offers sufficient friction to prevent skidding. The Fedi methods are worth the investigation of American contractors.

Except one-course concrete, all pavements are laid on some kind of base or foundation. Concrete itself is the base most frequently used for new work. Whether to use rich or lean concrete, reinforcement and joints is a puzzling question. In city work, where cuts in the pavement are frequent, reinforcing steel is a nuisance, and so the designer is tempted to lay a richer mix, forgetting that such mixes crack worse than lean ones and that cracks in the base almost invariably show up in the surface later on. Joints also show through to the surface in time and therefore may be looked at askance. On rural roads the best solution (until we have the perfect joint) may be the lean mix with light reinforcement. In cities that are growing it is probably well to leave out the steel and to add an inch or two in depth of concrete. In spite of the apparently excellent results in Washington, D. C., where joints and reinforcement have been used to good advantage, the writer believes that the *average* city will get better and cheaper results by the methods just indicated.

Further, there is the additional expense of joints and steel, which will make the cost mount so rapidly that sheet asphalt, asphaltic concrete and brick pavements will be possible only in those regions where freight charges are very low or non-existent.

The V-shaped center joint is of little value. If the perpendicular edges of the joint separate as much as 1/16 in., then the V-section separates by the same amount, and, unless tied together by steel, there is no point of contact between the slabs, and, consequently, neither supports the other. In lapped joints the sliding of one piece of concrete over the other is of more than doubtful value; such sliding may take place a few times, but ends when the joint becomes full of extraneous matter. The true tongue-and-groove joint also ceases to function when dirt, crushed aggregate or the like enter it.

There is a booklet on joints by L. J. Mensch. He gives us a historical review of joint designs since 1885. The booklet also gives us an analysis of stresses in slabs, dowel action and the requirements of good joint practice. We also have in the 1935-6 convention proceedings of American Road Builders Association a discussion of joints and joint compounds which is led by H. F. Clemmer and followed by various manufacturers. It would seem from reading these discussions that everyone has a joint and a filler, and yet the fact remains that none reaches perfection.

Concrete curbs are laid to a greater extent than any other type. All too often they are finished much as a baker ices a cake. The process of finishing the surface smoothly induces the worker to pull over the bulk of the concrete a layer of fines that is not integral. Furthermore, the curb is seldom thoroughly tamped or vibrated and hence its structure is like a honey-

comb. It tends to draw and hold water. This freezes and thaws throughout the winter and eventually the "icing" is broken off in chunks. The curb soon deteriorates. Often, too, no care is taken to see that room for expansion is provided. Many failures are due to this.

Concrete in curbs should be particularly well vibrated or tamped immediately after it is placed in the form. It should be dry, and the facing tool should be used as little as possible. Reliance should be placed on the vibrator. The granite curbs of those towns where such stone is available are superior to concrete, but they are much more expensive in first cost. However, they last forever.

Brick has its troubles

Paving brick require a sound base, a cushion that stays put and a filler that permits expansion and contraction of the brick and still is eternally waterproof. Brick have been laid over any and all sorts of foundations, but concrete is the one usually specified. If this base cracks to such an extent as to permit the loss of some of the cushion course, then a low spot in or a failure of the wearing course is certain. Many engineers prefer a lean concrete, since the cracks in it will be thinner than in a rich mix. Concrete base is laid from 5 to 7 in. thick, depending on soil and traffic. Over this is spread a 1-in. cushion course of sand and bituminous binder. The brick are laid directly on this, and their joints are filled with bitumen.

The filler has been causing trouble since the first brick was laid in Babylon. Interesting tests have been conducted in Ohio, and R. R. Litchiser, of the Ohio highway department, says certain fillers were satisfactory on the Ohio test road in 1936, and are worth further study.

If the base is as carefully constructed and finished as a concrete pavement, if the mastic cushion has at least 6 per cent by volume of binder of the proper grade, if the excess filler is removed before the pavement is opened to traffic, and if the brick are first class, there is no good reason why a remarkably easy riding pavement may not be built to last indefinitely. For rural roads the concrete base should have the curb flush with the brick top. This curb should be about 1 ft. wide; then it will provide a thickened edge for the base. On city streets the curb will project above the brick. De-aired brick has made its appearance, but it is too early to say anything about its performance. Clean brick are not slippery. A slight film of asphalt over the surface makes the brick road dangerous.

Bitumens need study

Those who have been on the job know that every once in a while the asphalt is said to be non-adhesive. It does not seem to cling tightly to the aggregate, and after a heavy rain it will be found that the aggregate has shed its coat of asphalt and has taken on water instead. This needs thorough study. At present only a few know much about it, and the rest are inclined to pass over it lightly. If it is understood by all that aggregates, like people, have their likes and their dislikes, that they take up with water in place of asphalt, or vice versa, then we shall be in a better position to talk about the adhesive qualities of bitumens. At the moment it is suggested that water-preferring aggregates be heated to drive off moisture and, while hot, be coated with hot water-gas tar. A deposit of carbon will be left on the aggregate. Asphalt sticks to carbon, the carbon is already on the aggregate and so water is repelled.

The sheet-asphalt pavement has been standard since the late seventies. It is slippery sometimes, especially when dirty; to make it more skidproof it is suggested that the final coating of the surface with either limestone dust or portland cement be omitted, and the pavement allowed to remain a dark color.

Changes proposed

Sheet asphalt is usually laid in two courses, each 1½ in. thick, on a concrete base. Lieut.-Col. Besson has suggested that the lower or binder course be omitted, and that a layer 1 in. thick be laid directly on the base. He cites such a pavement laid in Washington over a granite-block pavement, and its success (*ENR*, Oct. 15, 1936, p. 539) leads him to think that much care in the selection of base, binder course and sand and filler is unnecessary. He has used sand graded for concrete work with success. He is not the first to try the sheet top without a binder course. Many cities and states have tried it, only to find that usually it pushes and waves until travel over it is almost impossible. However, in the southern part of California it has been successful.

It will do no harm to try out several sections using a 1-in. thickness of top. B. E. Gray says that if the subgrade is firm a very thin ribbon-like application of bitumen will serve to carry any amount of traffic. Let us try it!

Asphaltic concrete is preferred by many highway engineers, especially on state or federal highway work. Not much change has been made in its mixes recently, and there is nothing to add. When properly built, of suitable materials, bituminous macadam gives good service. All too often its failure can be traced to ignorance, stupidity and greed. There are many miles that have stood up well for years, and today are in excellent condition. Both tars and asphalts are suitable. Sometimes both materials have been used—tar for the first coat and asphalt for the seal. This is satisfactory. It is the cheapest form of pavement, but it requires vigilant maintenance.

Ready-mixed cold-laid coaltar pavements are now satisfactory and may be laid during late spring, summer and early fall. In 1926, when this type was first laid in America, the top course was somewhat coarse in texture. This tended to reduce skidding to zero and to make the road exceptionally safe. For the speed and the tires of eleven years ago it was all right; but it was found that as the larger size balloon tires appeared and as the speed of cars increased the coarse surface was whisked off by traffic. It is now thought that the best plan is to put on a relatively fine cover, bound with sufficient tar to hold it in place, and to let the oxidizing effect of the weather produce a sandpaper finish. Results indicate that the idea is correct.

Problems of other types

Amiesite pavements have proved popular, when laid with sufficient skill and care. This pavement is like the little girl who was very very good or else she was horrid; it is horrid only when mixed improperly and laid in the wrong season. Great trouble is experienced with all of the cold-lay types in cool to cold weather, since they are almost unmanageable at low temperatures. This is also true of rock asphalt products.

Much use has been made of rock asphalt in thoes sections of the country where freight rates do not operate against it too severely. The pavements so laid are skidproof and wearproof to a great extent. The chief difficulty is to secure uniformity in the asphaltic content. If this trouble is corrected there should be much rock asphalt sold for maintenance work and as a cushion for brick and block pavements, as well as for black top itself.

Conclusion

The chemist, the physicist, and the engineer have too long been separated. They should come in under one banner for the good of the cause. Without their cooperation we are badly hindered. The contractor may do some very wild things if left to his own devices. He does not know the difference, perhaps, between the different portland cements, between asphalt and tar, between cutbacks and emulsions, and he needs the help of others. Chemists and physicists do not agree on some matters connected with these roadbuilding materials, and they should be brought together, on the job, to read, mark, learn and inwardly digest the troubles of engineer and contractor. State and federal geologists should be in the picture. With the help of these agencies we shall learn much that we still need to learn about the design of road surfaces.

Research Needs Coordination

National and state roadbuilding agencies now base their selection and use of materials and processes on laboratory and field research, but in present knowledge many gaps remain to be filled by coordinated investigations—New material specifications needed.

AGENCIES *enumerated by* . . . . . R. R. LITEHISER, *Chief Engineer of Tests, Ohio Department of Highways*
ACCOMPLISHMENTS *reviewed by* . . . . F. C. LANG, *Highway Engineering Dept., University of Minnesota*

EDITOR'S INTRODUCTION

VIRTUALLY every material used in modern roadbuilding is specified and its compliance with the specification is checked by test. This close laboratory and field control has come about in the last two decades.

Grown to astounding dimensions, as indicated by the articles that follow, highway laboratories originated as small groups of workers with a few appliances for making routine tests. This mediocre position soon failed to measure up to the growing requirements of laboratory service. New materials and new traffic requirements for roads were developing overnight and their claims had to be searched out and their demands provided for by increased testing and experimentation.

The step from here to original research was only a short one and the highway testing laboratory today has become a research laboratory in addition; in its cooperative work with other research agencies it is establishing the science of materials behavior upon which road design is based. The extent to which highway research has developed is told in the first article that follows. A second article reviews work accomplished and points out the gaps yet to be filled in.

Research an Integral Part Of Highway Design .....*R. R. Litehiser*

THE ROADBUILDER today does his work with very definite knowledge of his materials supplied by testing engineers. Every state highway department has its testing laboratory, and in most states these are also research laboratories. In addition both testing and research are carried on by individual materials producers, by associations of materials producers, by federal departments, by engineering colleges and by commercial laboratories. Thus the highway designer has available and constantly utilizes a wide range of testing and research laboratory service.

Research to develop and improve materials for highway construction was formally recognized by the Bureau of Public Roads upon its creation (1916) by including a division of tests in its organization. The division of tests of the bureau has conducted and is continuing valuable research in the field of highway construction materials, the results of which are made available to state highway departments by recommending specifications for materials and practices and through the bureau publication *Public Roads*.

While the bureau has had much influence over the testing activities of the different highway departments, the older departments, among them that of Ohio, had previously included in their organizations a testing engineer or engineer of materials, whose duty it was to determine the fitness of materials with which to construct highways. This duty was extended, as highway building assumed greater proportions, to include research directed toward improving these materials.

The function of the highway testing laboratory is twofold: routine testing of materials in current use to determine their compliance with the specifications under which they are furnished, and research study of new materials and methods. The first function frequently brings to light information of distinct value in modifying existing specifications so as to secure materials better suited to their purpose.

The other function, study of materials and methods, is carried on through two principal channels, namely, research of the laboratory's own undertaking and cooperation in materials research with such groups as the division of tests of the Bureau of Public Roads, other highway testing laboratories, the committee on materials of the American Association of State Highway Officials, the Highway Research Board, the American Society for Testing Materials, and the research divisions of material producer organizations. The advantage of cooperative research is so generally recognized that most highway testing laboratories make this type of research their major activity.

In either activity, the highway testing laboratory follows a similar plan. First, studies are carried on in the laboratory until results are sufficiently convincing to warrant trial on a field scale. Then the material (or it may be a method of handling or making a material) is tried out on a construction job with which continuous contact is maintained during construction and of which periodic inspections are made after completion, in order that field performance under actual traffic and weathering conditions may be known. The experience gained is used in modifying existing specifications—or in case of new materials in preparing new specifications.

A most valuable recent aid in research in highway construction materials is the circular track, such as is utilized by the Bureau of Public Roads, by several highway testing laboratories and by at least one material-producer organization. This makes it possible to carry to a greater degree of finality the

less expensive study in the laboratory and thus to minimize the extent of costly large-scale field tests.

At the present time few highway construction materials are accepted as the last word in their particular field. Laboratories are at work on cement, aggregates and concrete, particularly with respect to building a greater degree of durability into pavements and structures. This involves the development and use of accelerated weathering tests on the ingredients of concrete as well as on concrete itself.

In the field of soil stabilizers, owing to the comparative newness of the so-called stabilized road, highway testing laboratories are devoting most of their interest to field trials of stabilizers on which the initial laboratory study has been done by the industries producing them. As a result of these field trials, correlated with laboratory studies of the stabilizers themselves, the relative merit of the several stabilizers is being determined, as is also the most satisfactory way of applying them.

Rarely today does a manufacturer offer his product without an account of the laboratory study and control involved in its development and manufacture and its performance under test. The highway testing laboratories are the proving grounds upon which these materials are given their final trial, strictly from the user's point of view, before their use in highway construction is recommended to highway departments.

Broad Gaps Are Still Open in Highway Research

.....J. C. Lang

TECHNICAL SKILL and a broad scholarship interest in materials research are vital requirements of the director and workers of roads laboratories. This is an increasing responsibility on highway administration. The materials engineer for a state highway department writes specifications for many different materials and sees that these materials comply with the specification requirements and are properly used. It is usually his duty also to supervise the combination of different raw materials, as in the field manufacture of portland cement concrete. Finally, he must carry on true research in connection with materials and their uses.

To do this work properly, a materials engineer has to keep informed on developments in the manufacture and uses of the wide variety of materials on which he has to pass judgment. He should be able to meet the specialist from any material company on an intellectual level, and also to convince the owner of the rejected local gravel pit that he knows what he is doing; he is in a much better position to do this if he is enabled and encouraged to participate in the work of national technical societies and to engage in research with men from different parts of the world who have similar interests.

Before discussing future research organizations, it is well to review what tests and research have accomplished to increase knowledge of some of the more widely used road materials, and to indicate gaps in knowledge that need to be closed by future research.

The bituminous materials used in highway work, generally classified as asphaltic products and tars, may be used in a number of different consistencies, from solids to liquids of varying viscosities at ordinary summer temperatures. There is considerable dissatisfaction among engineers about practically all the current specifications for these materials.

The asphaltic products may be divided into the asphalt cements, which are solid or semi-solid at ordinary summer temperatures, and the liquid asphaltic products such as road oils, cutbacks and emulsions. The present specifications for asphalt cements are for the most part based on tests developed during the last century—tests devised to identify a few asphalts that were giving good service in eastern pavements at that time. Since then asphalts have become a common construction material over the entire country, they are derived from various petroleums, and the manufacturing methods are different from those in use when the tests were developed.

Many engineers are of the opinion that unsuitable asphalts may comply with the present standard specifications. Some have written special test requirements to get material from a certain geographical area or to exclude products manufactured in some particular manner: Fluidity factor, sulphur content, Oliensis spot test and low temperature ductility, are among the tests developed lately for these purposes. But other engineers are of the opinion that specifications based on these special tests exclude asphalts from which satisfactory service has been obtained.

There are even more misgivings about the liquid asphaltic products, especially the road oils, or, as they are now commonly designated, the slow-curing oils. The road oils were first used as dust palliatives and later for mat construction of dense-graded mixtures. In the beginning crude petroleum was used, but later it became the practice to use liquid residuums. As road oil came into more common use, engineers in different parts of the country started writing specifications for the product they wanted. These specifications usually included requirements for viscosity; the percentage of volatile under some evaporating condition; and the old basic tests on the asphalt-cement residue. For a time there were nearly as many different specifications for road oils as there were consumers. This was unsatisfactory both to the manufacturers, who had to prepare many products, often varying only in minor details, and to the engineers who wished to compare results.

Lately the Bureau of Public Roads and the Asphalt Institute have performed a real service by obtaining greater uniformity in specifications for the medium- and rapid-curing cutbacks and the slow-curing oils. The specifications for cutbacks are now practically the same throughout the country, and the specifications for both the cutbacks and the slow-curing oils come from the use of the special identification tests previously mentioned.

The Bureau of Public Roads and the Asphalt Institute did not attempt to standardize the specifications for asphalt emulsions. The emulsions are not as widely used as the other liquid asphaltic materials, and as yet the specifications for them are in a formative period. Any improvements that are made in the specifications for asphalt cement also apply to asphalt emulsion. There may be some question as to the significance of other tests, such as demulsibility and stone coating. Some engineers are of the opinion that there is no relation between the breaking of an emulsion when a calcium chloride solution is added and the breaking of the emulsion under field conditions. The stone coating test gives information concerning the ability of the emulsion to coat the stone, but the expressed results depend too much upon the judgment of the operator.

It would be very helpful if new tests were developed which would show directly the necessary properties of cementitiousness and durability. These, with the present tests for consistency, volatility, bitumen content and flash point, should be sufficient, and the engineer could then be sure of safety, of ease in handling and of service behavior on the road. The specifications should so define the quality desired that it would not be necessary to tell the manufacturer where he must obtain his crude oil or what methods he must or must not use in manufacturing. The resolutions passed at the recent Montana Bituminous Conference and at the National Road Oil and Asphalt Congress show that both consumers and producers realize the need for cooperative research to establish fundamental data

upon which more suitable specifications can be based.

Specifications for tars have not received as much publicity as those for asphaltic materials, but most of the objections to the latter apply equally to tar-products specifications. At a recent meeting of the committee on materials of the American Association of State Highway Officials a specification for fourteen different grades of tar was adopted. This specification is no doubt as good as can be written at the present time, but there is nothing in it to measure service behavior on the road, such as cementitiousness and durability. All that the specification covers is viscosity, volatility, purity, bitumen content, freedom from excess water, specific gravity and general requirements to exclude petroleum products with the exception of water-gas tar. It is certain that there may be considerable difference in the road behavior of tars conforming to this open specification.

Cement still a problem

About a decade ago it appeared as if both manufacturers and consumers were perfectly satisfied with the cement then manufactured. There continued to be much research with a view to finding new and better ways of making and placing concrete and it was generally realized that further study of aggregates was desirable, but it seemed to be felt that there was no more need of trying to improve cement than of trying to improve granite. Naturally under such conditions there was alarm among manufacturers and some misgivings among engineers when the Missouri highway department announced, in 1926, that it intended to raise the seven-day tensile requirement on briquets from 200 to 225 lb. This was heresy!

Since that time, as everybody knows, the standard specification for portland cement has been changed on the strength of new data obtained through research and experience, and changes will probably continue for many years to come. Producers as well as consumers are very active in research cements and concrete.

A criticism of the present standard specification is that, while the tensile test requirements have been raised, no other changes have been made. As an example, the old and present requirements for fineness are meaningless when applied to the modern cements. At a recent meeting the highway officials' committee on materials went on record as favoring the "specific surface" method for specifying fineness. The development of the turbidimeter for measuring surface area is a recent achievement in research on cements.

In addition to the changes in normal portland cements, progress has been made in the manufacture of high-early-strength portland cements and of cements that generate less heat during the early setting period. While the e may be some temporary confusion, it appears certain that in the future there will be special cements manufactured for different uses. A so-called standard portland cement may be entirely satisfactory for most purposes, but for special uses, as where great setting heat

MEASURING ROAD ROUGHNESS is a check on the accuracy of construction and a resource of modern research in studying wear and other behavior of surfacing materials.

is detrimental, it may be desirable to sacrifice some early strength to avoid excessive volume change. Where there is exposure to acids or alkalis it may be advisable to change the chemical composition of the cement to obtain durability. These are duties of further research.

At the present time there is need for some rational method of evaluating the different cements according to their concrete-making properties. Laboratory tests frequently indicate that concrete made with one cement is stronger and more durable than concrete made with some other cement; yet there does not seem to be any practical method of applying this information when receiving bids on public work.

It is evident that a special cement at a higher cost per barrel than a normal portland cement may make concrete of the required strength and durability at less cost, but it is difficult to devise any method of purchasing cement on a sliding scale based on quality. There are usually many cements available for any job, and while there may be large differences between the concrete-making properties of some, others may differ but little when measured on a strength basis.

An early-strength test is not fair, because some good cements set slowly; there usually is not time to wait for long-time tests before making the contract award, and if the award were made on a close margin the quality of the cement would have to be watched very closely during construction. Nevertheless it seems basically right to pay according to quality, and let us hope that some large consumers will devise a way to do so. It would stimulate research in the manufacture of portland cements. We definitely need a short time method for determining the quality of cements as to strength and durability.

There has been a large amount of research on aggregates for concrete. The American Society for Testing Materials published a symposium on Mineral Aggregates in 1929, and later (1935) a report on the significance of tests of concrete and concrete aggregates. The American Association of State Highway Officials and the American Society for Testing Materials have published specifications for aggregates for portland cement concrete.

Aggregates need study

No excuse exists today for the old-type specification which stated that the aggregates should be clean, hard, durable, free from adherent coatings, well graded and should not contain an excess of flat and elongated particles or deleterious substances. In the present A.S.T.M. specification, thirteen different test methods are given for measuring the quality of aggregates.

Important research work on aggregates now under way is an investigation of the Los Angeles rattler test to replace the Deval abrasion and the toughness tests. The Los Angeles rattler test is made in fifteen minutes on a plant-run sample and gives more concordant results; it will probably be used by many state highway departments as soon as enough data are available for specifying suitable test limits. A report on magnesium and sodium sulphate tests for durability of aggregates was made by the committee on mineral aggregates at the last meeting of the Highway Research Board; it seems to be the general opinion that these tests are of value for information, but the erratic results frequently obtained make their use inadvisable as a specification requirement.

There are other items on which we need further information before specifications can be made definite. Some of the present test limits are questionable. We still leave the rejection of most deleterious substances to the judgment

IMPROVED ALIGNMENT cuts out a sharp kink in the old road, regularizes the profile and gives more flood headroom at the bridge; stabilized shoulders and a wide bridge represent advanced practice which calls for flatter cut slopes to increase sight distance on the curve.

of the local engineer. Some specifications set limits on coal, clay lumps and shale, and name other objectionable substances. In the past, aggregates have been considered as inert particles bound together by a cement paste, but tests have shown that the strength of concrete varies according to the mineralogical composition of the aggregate. In the future, perhaps consideration may have to be given to still other properties, such as absorption, adsorption, acidity and polarity.

There are many different types of bituminous roads and there is considerable variation in the specification requirements for the aggregates. In general, the same test methods may be used for measuring structural strength, durability, cleanness and gradation that are used for aggregates in portland cement concrete; the test limits will vary according to the type of surface and the materials available.

An important consideration in selecting aggregates for use with a bituminous binder is whether an aggregate is hydrophilic or hydrophobic. The bituminous coating on a hydrophilic aggregate separates from the stone in the presence of water; such a stone has a greater affinity for water than bitumen. The bitumen coating on a hydrophobic aggregate cannot easily be displaced by water. So-called stripping tests for measuring this property have been developed by a few investigators, but as the test has not been standardized it has not generally been used in specifications for aggregates on bituminous work.

Hydrophilic stone may safely be used if its properties are modified by introducing some admixture. Again there is a difference in the stripping action of different bitumens. More research work is urgently needed to determine causes of stripping and to develop corrective measures.

Soil stabilization

Until the past four or five years it was general practice to use pit-run gravel in gravel surfaces. Many engineers considered that gravel roads would not be economical if the cost were increased by added refinements. But in recent years the stabilized gravel road has been developed, and specifications have been formulated that place the design of such surfaces or bases on an engineering basis. We now have a definite method for ascertaining when the gravel has the correct grading, and for selecting and proportioning the clay binder.

Much progress has been made in the past three years in improving natural soils; there have been some very encouraging field experiments using portland cement, tar, asphalt emulsions, road oils or cutback asphalts. Laboratory research is also under way. Some of our best engineers are working on the problem, and it should be only a matter of time until definite procedures are established. It is a fertile field for research.

Surveying the highway research work of recent years one is bound to say that it has not been highly efficient. Organization was and is inadequate. The work is carried on largely by enthusiastic individuals in various parts of the country, some of whom plan their work well and carry it carefully through to fruition while many others start without thorough advance study of the problem or knowledge of what has been accomplished by others. These latter investigators soon become entangled in the many variables encountered and give up, and accomplish little beyond increasing their own knowledge.

If the novice could be sufficiently guided, he would contribute to our knowledge and maintain his own interest. As a result, there would be an ever-increasing number of competent experts making valuable contributions to our highway progress. This might be accomplished by means of some central agency that would maintain a corps of consultant experts to advise how to proceed with an investigation, and also to assist in compiling and evaluating the data. There should be some field men to contact the local research workers for the purpose of stimulating enthusiasm and emphasizing accuracy. The Highway Research Board appears to be the proper central agency for carrying on such work. Unfortunately, sufficient funds for this purpose are not available; an endowment could be used to good advantage.

Line and Profile Improvement

New standards of alignment, grade and across-road dimensions and profile are developing from experience; rational methods of design, are practicable only in a few details—Reconstruction and modernization of existing highway facilities bring problems of a new character

GOVERNING REQUIREMENTS *stated by* . . . . . C. N. CONNER, *U. S. Bureau of Public Roads*
UNIFIED ROAD AND TRAFFIC PATTERN *urged by* . . . . . PROF. W. G. McNOWN, *University of Kansas*

EDITOR'S INTRODUCTION

IN DEVELOPING present highway systems the first consideration was to provide connected routes with travelable surfaces. Design thinking centered on producing smooth durable trackways. These encouraged increased travel volume and speed and design for operation pressed hard for attention.

Without disregarding surface, design thinking turned to line and profile and to width and shape of roadway cross-section. Gradual at first, this change of attention has turned sharply upward in the last few years. To day there is a fairly well rounded design practice as outlined in the articles that follow, governing line design, longitudinal profile and roadway cross-section. This practice is particularly important to consider because it does not apply to new roadbuilding alone.

A second era of road improvement that now confronts highway engineers is the reconstruction and modernization of existing highway operating facilities. We are faced with highway obsolescence now because twenty or even ten years ago we had little foresight of highway transport problems to come.

Design Trends To Correlation with Traffic Needs.....*C. N. Conner*

PRESENT SPEED and traffic requirements have set higher standards of design that call for modernizing old roads and building new roads to better line and profile. Obsolescence and its fatal effects on traffic are greatest on main highways constructed ten and fifteen years ago to designs then suitable for local needs but which are now inadequate and unsafe. Vehicles now travel about twice as fast as then, traffic volume is many times as great and radius of travel is unrestricted. The need to improve these old trunk highways to standards adequate for safe travel is imperative; whether the improvement calls for the revision of existing alignment or a new location is to be decided for each particular case.

Any road can be modernized by reducing curvature, producing longer sight distances; superelevating, spiraling and widening curves; widening roadways; filling deep ditches, and placing warning signals. We must recognize, however, that not more than about 5 per cent of the 324,000 miles of state highways can or will need to be advanced beyond the stage of adequate two-lane improvement. The cost of building this 5 percent to four-and six-lane widths would be about four billion dollars, which is more than we are able to pay in the near future.

With these facts in mind consideration is given here to some of the elements of best present practice in the design of alignment, profile and cross section in their relation to safe and comfortable travel. The roads considered are those clear of urban areas, classed by the American Association of State Highway Officials as Class B roads, carrying daily from 750 to 4,000 vehicles and, to a lesser extent, Class A roads, carrying 4,000 or more vehicles.

Travel Speed

Each detail of a highway can, within reasonable limits, be designed for a designated speed. Under present-day conditions primary roads should be designed to permit safe operation at a speed of 60 miles or more per hour in non-mountainous country and at least 40 miles per hour in mountainous areas. Designs should also be balanced throughout the length of a road so that the driver is not suddenly confronted with abrupt changes in alignment, grade, cross-section or traffic conditions calling for unreasonably low or dangerously high speeds. Unavoidable obstacles may require a short part of the highway to be designed for a speed lower than that for the highway as a whole, in which case conspicuous pavement markings, signs, signals or other traffic-control devices of uniform design and general application should be used to warn the driver of approaching danger.

Vehicles and grades

The present range in weight, speed and power of vehicles is wide, but there is a steady trend to greater power and speed in both trucks and passenger cars. Grades are important because of their effect on the heavier and slower vehicles. The performance of heavy trucks on upgrades indicates the limit of a highway to carry without congestion relatively large volumes of traffic.

The rated capacity of modern trucks of the 1½-ton class shows them to be capable of a speed of 30 miles per hour on 5 percent grades. This is the most numerous class of vehicle transporting goods. An increase of grade to 6 percent reduces the rated speed of most trucks to or below 30 miles per hour. On 5 percent grades the heavier trucks

(5 to 7½ tons rating), having a gross vehicle weight of from 15 to 18½ tons, are now capable of speeds, in some cases, approaching 30 miles per hour, but because of grade to 6 percent reduces their speed in most instances to 20 miles per hour or less.

The average combustion engine loses about 3 percent efficiency for each 1,000 ft. of altitude. On a grade at an elevation of 10,000 ft. an automobile or truck is only 70 percent as efficient as at sea level. Thus highway grades in high altitudes need to be flatter than at low elevations. Actually many trucks now on the road slow down to 5 or 10 miles per hour near the summits of long sustained grades, and on two-lane and most three-lane roads cause unjustifiable delay and congestion.

The difference in rated capacity and actual loading of trucks on the road has resulted in a confused record out of which the engineer can with difficulty derive facts which he can apply to the design of grade, curvature and sight distance. J. T. Thompson, highway research specialist, U. S. Bureau of Public Roads, and professor of civil engineering, The Johns Hopkins University, in A Study of the Weights and Dimensions of Trucks, (*Public Roads*, May, 1935) makes clear that the heavier loading of smaller units in relation to capacity is evident, and that the heavier gross loads are not by any means carried exclusively on vehicles of the larger rated capacity classes. On the contrary, the smaller rated capacity classes are represented by significant numbers of vehicles in each group up to the 30,000-lb. limit. Professor Thompson says: "Loading in excess of rated capacity is far more prevalent in the case of small trucks than large ones. On the average, the 1½-ton trucks were found to carry one and two-thirds as much as the recommended load, while the 5-ton trucks averaged, just about their rated capacity load. In extremes, the smaller truck is loaded to four, five and even six times its rated capacity; the larger one is seldom loaded more than twice its capacity." The engineer should consider data of this character in relating vehicle capacity and power to speed on grades.

Present recommendations of the American Association of State Highway Officials call for a desirable maximum grade of 5 percent on roads having more than two traffic lanes and carrying 4,000 or more vehicles daily where more than 15 percent of the total traffic is commercial, otherwise 6 percent maximum, and on two-lane roads carrying from 750 to 4,000 vehicles daily a maximum of 5 per cent where feasible but not more than 8 percent in any case. Present practice indicates that in non-mountainous areas grades of 5 percent which are more than 500 ft. long may well be flattened; and that in mountainous areas grades of 8 percent and more that are longer than 500 ft., and involve considerable curvature should be improved by grade reduction, compensation on sharp curves or the addition of a traffic lane for slow traffic.

Sight distances

Sight distance involves volume and speed of traffic, number of traffic lanes, vertical curvature and horizontal curvature. It is recognized that sight distances on four-lane highways may safely be shorter than on two-lane roads, and that on three-lane roads sight distances must be longer than on either four-lane highways or two-lane roads. Sufficient recognition, however, is not given to the fact that the principles of safe highway design greatly limit the application of the three-lane highways. The safe use of three-lane highways is limited because in most topography adequate sight distances are not obtainable at reasonable construction costs. A third traffic lane added to a two-lane highway to carry slow moving traffic on long steep upgrades, if physically separated from the other two lanes by a suitable barrier, would facilitate the free flow of traffic and reduce accidents.

The general feeling is that 1,000 ft. is the shortest sight distance that may be regarded as reasonably safe on two-lane roads to be traveled at 60 miles per hour. In a distance of 1,000 ft. a driver of a vehicle moving at 60 miles per hour can normally pass another vehicle moving at 40 miles per hour and avoid collision with an approaching vehicle traveling at 60 miles per hour. If the difference in speed between the overtaking and overtaken vehicle is large the safe passing distance is much less than when the difference in speed is small. If more than one vehicle is to be passed the safe sight distance must be greater. Road conditions related to safe passing distance need further study.

On primary two-lane highways in non-mountainous areas sight distances of 1,000 ft. or more should be readily obtainable, whereas in mountainous areas it may be difficult to obtain as little as 650 ft. Sight distances on four-lane highways having parkways or median strips separating the opposing traffic lanes may be reduced appreciably below those on two-lane or three-lane roads because the possibility of accidents on them is limited largely to rear-end collisions. The safe sight distance for four-lane roads, therefore, should be at least that distance in which a moving car can be brought to a full stop. It will range from 300 to 700 ft. depending on the speed and braking power of the vehicles involved. The American Association of State Highway Officials recommends a minimum sight distance of 500 ft. for four-lane roads and 800 ft. minimum on other Class A and B roads.

In hilly and mountainous areas the sight distance is usually limited because of frequent horizontal and vertical curves, and sight distances of 500 ft. on existing main highways are not unusual. A combination of horizontal and vertical curvature is not safe and causes congestion and accidents. Where short sight distances cannot be avoided designs should provide at frequent intervals sections of alignment where the sight distance is sufficient to permit overtaking and passing in safety. Rolling grades are economical and not objectionable except where secondary rolls produce short blind sections or pockets that are not seen by drivers until an oncoming vehicle unexpectedly surges into view.

On long upgrades where sight distances are too short for safe passing two-lane highways should be widened to four lanes or a third lane provided solely for the slower moving vehicles on which they would be forced to travel while being passed by faster vehicles.

Designs of grade lines which reduce first cost by balancing quantities of cuts and fills are less desirable than designs which make possible the economical operation of vehicles, freedom from congestion and the elimination of hazards. Safety and utility on main highways must not be sacrificed to reduce construction costs. Life is more valuable than earth and rock.

Horizontal curvature

Most designs call for alignment consisting of a series of tangents connected by simple curves. Except for the monotony of driving by day and the disconcerting, blinding glare of headlights by night long tangents may be traveled in comfort at maximum speeds. Slight changes in direction are desirable but abrupt changes are always a source of danger. A short-radius curve hidden from view at the end of a long tangent constitutes a serious hazard. On primary roads in non-mountainous areas a 6-deg. curve (about 1,000 ft. radius) is considered to be a reasonable maximum, and in hilly and mountainous areas a curve of 14 deg. having a radius of about 400 ft. is a desirable maximum but is not always attainable in the most rugged areas. Every effort should be made to avoid sharp curvature on steep grades. Compound curves and reverse curves are not in general use on primary routes under the jurisdiction of state highway departments, but they have been used satisfactorily in difficult mountainous topography for boulevard and park road construction.

The American Association of State Highway Officials recommends a minimum sight distance of 800 ft. on horizontal curves. In mountainous country a clear sight distance on horizontal curves of 500 or 600 ft. for design

VAGARIES OF ALIGNMENT on a prairie road that had a record of many accidents were reduced by relocation according to advanced practice.

speeds of about 40 miles per hour is considered reasonable. The minimum sight distance in any case should be greater than the braking distance of the vehicle for the maximum safe speed on the curves involved. The best designs provide an easy flowing alignment restful to the traveler and free from sharp curvature or unusually long tangents likely to prove dangerous for the average driver.

Spiral Transitions — Transitions should be used for all except extremely flat curves to encourage the driver to remain in his lane and to provide a smoother riding highway of pleasing appearance. A theoretically exact transition curve is complicated and its mathematical solution difficult. The average highway engineer has believed spiral transitions too complicated for field and office work; transition curves will become a fundamental part of highway alignment when accurate methods of computation are developed which are sufficiently simple for practical use. Drivers cut corners on curves without transitions because of a natural tendency to reduce the shock of the sudden application of centrifugal force in changing from a straight to a circular motion, and because it is difficult to maintain a maximum uniform speed when holding the vehicle in its proper traffic lane.

The length of transition is sometimes obtained by the formula $1.6 \frac{V^3}{R}$

Where V is the speed of the vehicle in miles per hour and R the radius of the curve in feet. Superelevation should be run off uniformly in the length of the transition. The length of transition obtained by the above formula permits a comfortable rate of run-off but is sometimes too short for good appearance. The length of transition therefore should be increased when the slope of the outer edge of pavement with respect to the normal center line is greater than 1 in 200 in all except mountainous terrain where 1 in 150 may be permitted.

Superelevation—The relationship between E the superelevation slope, F the side friction factor, V the speed of a vehicle in miles per hour, and R the radius of curve in feet may be represented by the formula

$$E + F = .067 \frac{V^2}{R} \qquad (1)$$

It is common practice to follow the latest recommendation of the American Association of State Highway Officials to design superelevation to counteract all centrifugal force wherever possible when a vehicle travels at an assumed speed of 35 or 40 miles per hour, and rely on varying amounts of side friction to keep vehicles on the road when they are traveling at greater speed. The formula is as follows:

$$E = .067 \frac{V^2}{R} \qquad (2)$$

which omits F, the side friction factor. Maximum curvatures recommended by the association for various classes of roads are based on traffic density.

Some engineers consider it wiser to base the design of curvature and superelevation on assumed design speeds using formula (1) and amounts of side friction which are considered safe. Recent tests indicate that a side friction corresponding to a factor of 0.16 may be used with safety up to a speed of 60 miles per hour and smaller factors may be used for higher speeds. The practical maximum superelevation slope is about 1½ in. per foot.

Widening — Pavements on sharp curves are widened to allow for the extra width occupied by a vehicle, or vehicle and trailer, and because of the difficulty of keeping in the center of the occupied lane. A modification of the formula for widening recommended by the American Association of State Highway Officials follows:

$$W = n\,(R - R^2 - L^2) + \frac{V}{R}$$

W is the total widening in feet, n the number of lanes, R the radius in feet, L the wheelbase in feet (20 ft. recommended), and V the speed in miles per hour. The first part of the expression represents the extra width occupied by a vehicle on a curve and the second part allows for the difficulty of keeping a vehicle in the center of the lane. Widening generally is added entirely on the inside of a curve. Where adequate transitions

are used widening may be made proportional to the distance from the beginning of the transition.

Roadway cross profile

We cannot reasonably expect to reduce accidents due to crooked and narrow roads unless we provide right-of-way sufficient for improvements designed for safety. To provide greater safety the Florida state road department now insists on a 200-ft. right-of-way for every new state highway. The Indiana state highway commission feels that the greatest contribution to motoring safety during the past three years has been widening rights-of-way, making it possible to widen shoulders, extend culverts and build shallow side ditches. Other states are calling for a minimum of 100 ft. for right-of-way on main roads including the Michigan state highway department which uses widths of 100, 120, 150, 200 and 204 ft.

Shoulders—Modern vehicles are less subject to breakdowns than those of former years and the need for parking on shoulders to make repairs is greatly reduced. The occasionally parked vehicle should be kept off the pavement. Commendable efforts are being made to provide extra shoulder width at rural mail boxes, bus stops and special parking areas just off the road where scenery may be viewed or vehicles repaired without obstructing traffic. Shoulders however have two other important functions, first, that of protecting the pavement from damage by water and melting snow, and second, that of providing an all-weather waterproof surface for vehicles in motion which have been forced off the pavement surface for any reason.

A desirable section for a modern two-lane highway of the classification under consideration is one having a paved width of 22 ft. and bituminous treated gravel, stone or slag shoulders having a minimum width of 8 ft.

Grass or sodded shoulders on heavily traveled narrow pavements cannot be maintained in a satisfactory manner at reasonable cost because traffic prevents the growth of grass and cuts the shoulders extensively. They are suitable only where traffic is relatively small in volume and where there are few buses or wide trucks likely to run off the pavement. Extensive pavement failures and fatal accidents may be traced directly to low and rutted shoulders. Lean and skimpy designs generally are responsible for numerous highway accidents, many of which could have been prevented if generous sections calling for wide bituminous treated shoulders, long culverts and wide bridges had been used.

Ditches—All roads should have adequate cross drainage and adequate side drainage. Intercepting ditches and berm ditches should be constructed outside the tops of heavy cuts. All ditches or gutters should, of course, have sufficient slope to carry the run-off water without erosion. Erosion of ditches is prevented by numerous well-known means such as paved gutters, ditch checks of stone, timber or other materials and plenty of pipe culverts under the road. Pipe placed below shallow side gutters parallel to roadways are used with success instead of deep ditches. Although relatively expensive as compared to deep, open ditches, they definitely reduce traffic hazards and provide adequate drainage at reduced maintenance costs. They may be the best solution to drainage resulting from inadequate right-of-way.

Present practice shows a definite trend toward the use of wider and shallower ditches rounded in contour.

Back Slopes—Current practice and present trends show slopes in cuts and fills to be more rounded and flatter than formerly. It is usual to find shallow fills 5 ft. and less in height having side slopes of 1 on 4 or flatter. In flat or gently rolling country sections calling for extra-wide fills and flat side slopes are used instead of relatively narrow fills having steep side slopes and guard rail. On the other hand, in difficult mountainous country involving steep side-hill cuts and retaining walls, shoulders and ditches are sometimes omitted entirely and an extra width of pavement with a paved gutter or curb is used instead. Grading costs are greatly reduced by this design.

Good Design Requires Vision Beyond Detail

.....*W. C. McNown*

EROSION of back slopes in deep earth cuts has been prevented or reduced by the use of wide terraces planted with suitable vegetation.

The most important job before engineers responsible for main highways is to provide adequate and safe traffic facilities at whatever cost within reason. A study of accident records and points of traffic congestion will show the dangerous spots in the highway and indicate the steps to correct them. Faults directly traceable to the driver or the vehicle, however, should not be charged against the design of the roadway.

Approaching stability

The road and vehicle pattern is taking final form permitting the highway engineer to fix the details of alignment and road cross-section with some assurance that they may remain adequate. The era of taking highway traffic out of the mud is passed. Highways are now in a similar position to that of the railroads half a century ago when terminii were connected and it remained to revamp the pioneer construction. The super highway is emerging and seems destined to absorb the primary system bit by bit as it extends outward from and between great centers of population. But highway transportation is not yet an entity. The separate agencies engaged in roadbuilding, motor vehicle manufacture, traffic regulation and accident insurance work separately upon vital elements of the general problem. Society, apparently without realization, pays the cost of the lack of coordination.

Do these ideas belong in a discussion of the details of alignment and roadway? One is obliged to think that they do. It is frequently well to consider the broader social aspects of an important engineering problem before considering the technical details. Let us do so!

There is no such thing as safe motor vehicle transportation; certain hazards are inherent in the setup. A prominent man, a good driver, fainted at the wheel and crashed into a culvert headwall; a truck tire came off and rolled into a passenger vehicle approaching from the opposite direction; a driver traveling at a high speed came to an inadequately superelevated curve and swung across the center line of the roadway into the path of an approaching truck; two women traveling at 35 m.p.h. had a blow-out and hit a concrete culvert headwall. These and many similar accidents illustrate the inevitable hazard. Note that without intention, culvert headwall appears in two out of four of the above accidents that occurred recently within a radius of 30 mi. of the place where this paper was written.

Again, the writer, traveling on an Iowa highway, saw the vehicle ahead leave the road, plunge down the slope and come safely to rest right side up in the bottom of a broad ditch. This incident not only illustrates another possible hazard, but allows the imagination to envisage the ideal highway. Let those responsible for highway control and design revamp the broad plan. The details will fall into the pattern.

The scope of this paper includes traffic regulation only insofar as regulation impinges upon the elements of highway design under consideration. It seems obvious that highways designed for unregulated traffic must of necessity be of a more generous pattern and consequently more expensive. The present regulation is casual, sporadic and to a

large degree, ineffective. It varies from no regulation in some states to an inadequate measures in others. The situation is confused.

Certain details of design are based upon speed. The ultimate traffic speed has probably not been reached. The final speed is much more likely to depend upon the capabilities of the driver than on those of the vehicle. It now appears that we are near enough to the ultimate speed to set limits for design purposes.

Other than for the fifteen per cent of the irresponsibles, elimination of poor drivers is not possible. The family car with its variegated coterie of drivers has its place upon the road; the ultimate highway speed under regulated traffic will be determined by the capabilities of this group. They may be expected to handle their cars safely at speeds extending from 35 to 60 miles per hour. The same limits may be placed upon the vehicles that they direct.

Superhighway speeds of 80 to 100 miles per hour are frequently mentioned, although the basis for setting such limits is not made clear. It is idle to assume that the limiting speeds upon any class of highways will be determined by the capabilities of a limited number of vehicles and a lesser fraction of competent drivers. It is still proper to consider the rights of the total group as being above the desires of a minority.

The cost of high speed upon highways has not been determined, neither as to wear and tear upon the vehicle nor as to the increased damage incident to accidents. It seems clear that the present-day light passenger vehicle cannot operate economically or stand the strain of the speeds for which it is powered.

Details of design

The technical details of the design of alignment and highway cross-section have been competently discussed, one need not repeat too much. There is only one place in such design where the several factors can be put into a formula, and that is in connection with the elements curvature and superelevation.

Other details, such as roadway and shoulder widths and the slopes and depths of ditches must be developed empirically with consideration of traffic flow and accident experience. The criteria have been discussed above. These details must not be too highly standardized; they must be suited to the topography and the alignment.

Highway design is an art as well as a science. One follows a road winding down from the upland to the valley. One feels a sense of restriction. Why? The road is not ample. It does not offer to traffic the freedom of the straighter and more level section that has just receded. Perhaps the designing engineer did not sense the necessity for a more generous plan or he may have been hampered by fixed standards or inadequate funds. The roadway width may have been increased by perhaps 2 ft., when 4, 6 or even 8 ft. of additional width together with other expanded details may have been needed to open this section to the free and safe flow of traffic.

One enters a straight, level section of highway having an excellent surface. It invites speed. Closer scrutiny discloses narrow shoulders, steep inner ditch slopes and a row of concrete culvert headwalls standing like tombstones close beside the way. One senses the inevitable hazard and adopts a moderate speed, or one accepts the invitation and gambles with a situation where the stakes are high.

Nor is it sufficient to replace concrete culvert headwalls with wooden markers. Below yawns the openings between trim, flaring wingwalls. Traffic must be protected from falling into these concrete lined pits. Traffic must not be invited into a snare.

The highway crosses the successive ridges between lines of transverse drainage. The grades are steep and choppy; it is difficult to obtain sufficient sight distance. This is a problem to be treated adequately in some manner. If the use of four traffic lanes, two extra for passing, constitutes the only solution, that fact should be recognized, otherwise there may be introduced a section of highway that is incomplete and unsafe.

Vision of the future

On certain first class railroads, trains are automatically controlled and brought to rest upon entrance into a closed block. There is nothing akin to this in highway operation. It merely reveals the ultimate in railroad traffic control. Railroad transportation once lacked safety. Hideous accidents resulted. It took a century of effort to realize in 1935 a year without an accident fatality. Is there not a similar goal for highway transportation? Shall we permit ourselves to say that highway transportation is so complicated and uncontrolled that it is not possible to approach the safety that exists in railroad transportation. Will the year 1995, marking a century of development since the advent of the first motor vehicle, be a year without a motor vehicle accident fatality? If this is to come to pass the loose ends of motor vehicle transportation must be gathered up and integrated into a single social entity.

EARTHMOVING EQUIPMENT is designed to aid in compacting material placed in highway building.

What is Known of Stresses

Old findings and new developments in interpreting results of tests and behavior of pavement in service—corner breaks in pavements and the reaction offered by the subgrade discussed.

By H. M. Westergaard . . . . . *Gordon McKay Professor of Civil Engineering, Harvard University*

KNOWLEDGE of the behavior of concrete pavements as structures is derived from experience with pavements in use, from tests and from theoretical analysis. The load tests directed at the beginning of the Twenties by the States of California* and Illinois** and by the United States Bureau of Public Roads*** helped the interpretation of the mass of observations accumulated in practice and speeded up the approach to a rational design of the cross section, not least by demonstrating the importance of the corner break.

Later test programs have had similar usefulness. Especially notable are those which have been carried out by the group of able engineers in the Division of Tests of the United States Bureau of Public Roads, and which have been reported from time to time mostly in the government journal "Public Roads." Particular attention is called to the latest link in this sequence of reports of research: a series of five papers by L. W. Teller and Earl C. Sutherland under the common title "The Structural Design of Concrete Pavements" (Public Roads, October, November, December, 1935; September, October, 1936, the closing paper still to appear). It might have been possible to do without the tests, but data from relatively few tests can be the equivalent of large quantities of slowly acquired observations in practice, and it can be asserted without hesitation that the sum total of the systematic structural tests have had a positive economic efficiency.

It is certainly plausible to question the need for the theoretical analyses. One could do without them. Decisions as to cross section, reinforcement, joints, proportioning of the concrete, and treatment of the subgrade do not require computations of stresses and deformations. Yet, the theoretical analyses have been of some use. As the data from tests have improved the efficiency of interpreting observations in practice, so have the theoretical studies helped in interpreting results of tests. And as the tests have assisted in shaping policies of design, so have the analyses helped in the intelligent planning of new tests. The current series of papers by Teller and Sutherland in Public Roads, to which reference was made, illustrates the latter relation of tests and theory. Moreover, formulas derived from theory have been used occasionally in arriving at decisions permitting or refusing the transportation of unusual loads over particular pavements; and the same formulas may be used for the purpose of apportioning the cost of pavements to the different kinds of traffic, with a view toward taxation of vehicles according to weight. It seems reasonable to assert that also the theoretical analyses have had a positive economic efficiency.

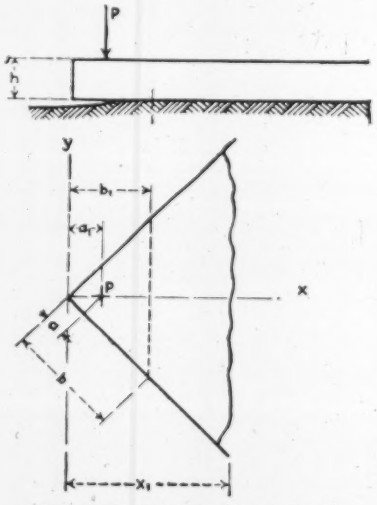

FIG. 1—DIAGRAM of analysis of a corner break in a concrete pavement.

The following discussion will be limited to certain phases of the development of the theoretical analyses.

The corner break

In 1922 it became known to the writer that both A. T. Goldbeck, then Chief of the Division of Tests in the Bureau of Public Roads, and Clifford Older, who at that time was Chief Engineer of the Illinois Highway Department, had arrived, evidently independently, at the following simple analysis of the corner break: The corner is formed by the edge and a transverse joint. The two adjacent slabs are assumed unconnected at the joint. The thickness of the slab is assumed uniform, equal to h, as in Fig. 1. The wheel load P is assumed to be concentrated at the point of the corner (making $a_1 = 0$ in Fig. 1.). At small distances from the corner the influence of the reactions from the subgrade will be small compared with that due to the load. The portion near the corner, therefore, may be considered to act as a cantilever with uniform strength. At the distance x, measured diagonally at angles of 45 deg. with the edge and joint, the bending moment is $-Px$, the width of section $2x$, and the section modulus $\frac{1}{3}\,xh^2$. Then the average tensile stress at the top of this section becomes

$$s = \frac{3P}{h^2} \qquad (1)$$

This simple computation offered an explanation of the frequent corner breaks that had been observed in pavements without stiffened edges. The analysis leading to equation (1) is the most important single step in the theory of stresses in pavements.

The load is actually distributed over some area of contact between the tire and the pavement. It was desired therefore also to examine the case in which the resultant wheel pressure is at a small distance a_1 from the corner, as in Fig. 1. In this case it could be anticipated that the reactions of the subgrade would have some influence and that the greatest stress would occur at some distance from the load.

At the initiative of A. T. Goldbeck the writer was engaged by the Bureau of Public Roads to make theoretical studies of the structural action of pavements due to the various important types of loading: load near a corner; load at the edge at some distance from the corner; load at a point of the interior of the area of a slab; and combinations of such loads. The results of this study were published in a paper entitled, "Stresses in Concrete Pavements Computed by Theoretical Analysis," Public Roads, April, 1926 (also in the Proceedings of the Highway Research Board, 1926, Part I, p. 90).

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* *Lloyd Aldrich and J. B. Leonard, "Report of Highway Research at Pittsburg, California, 1921–1922," California State Printing Office, 1923. The Bureau of Public Roads cooperated.*

** *Clifford Older, "Highway Research in Illinois," American Society of Civil Engineers, Transactions, Vol. 87, 1924, p. 1180. The Bureau of Public Roads cooperated.*

*** *For example, C. A. Hogentogler, "Tests of Impact on Pavements by the Bureau of Public Roads," Public Roads, October, November, 1921. Or, at a later stage, L. W. Teller, "The Six-Wheel Truck and the Pavement," Public Roads, October, 1925.*

The question of the reactions offered by the subgrade is complex and could never be free from uncertainties. Generally, the greater the deflection, the greater the reaction. It was assumed in the analysis that when the conditions of the subgrade are not abnormal, a deflection z is accompanied by a reaction kz per unit of area, k being a constant for a given slab and given type of loading. The coefficient k was called the modulus of subgrade reaction, and is measurable in pounds per square inch per inch deflection, that is, in pounds per cubic inch. This assumption of a constant modulus of subgrade reaction when the subgrade is not abnormal was recognized as a compromise between reality and simplicity. A justification was found in the fact that the stresses derived were not very sensitive to changes of the modulus k; for example, a change from 50 lb.in.$^{-3}$ to 200 lb.in.$^{-3}$ produced relatively minor variations of the computed stresses. Furthermore, the test data available at the time supported the assumption that k could be taken as a constant as long as one dealt with a given pavement on a subgrade in a given condition.

It was found expedient to introduce a further quantity, which measures the stiffness of the slab relative to the stiffness of the subgrade. This constant was called the radius of relative stiffness. It is denoted by l and is defined by the formula

$$l = \sqrt[4]{\frac{E\,h^3}{12\,(1-\mu^2)\,k}} \qquad (2)$$

in which

E = modulus of elasticity of the concrete,
μ = Poisson's ratio of lateral contraction to longitudinal expansion of the concrete, and
h = thickness of the slab (assumed constant).

In practical cases l will be of the order of magnitude of 30 to 40 in.

The following approximate formulas were obtained for the case of a load near the corner, in the position shown in Fig. 1, when the subgrade offers support over the whole area:

$$z = \frac{P}{k\,l^2}\left(1.1\,e^{-x/l} - \frac{a_1}{l}\,0.88\,e^{-2x/l}\right) \qquad (3)$$

Distance x to section of maximum stress, roughly:

$$x_1 = 2\sqrt{a_1\,l} \qquad (4)$$

Maximum tensile stress in a diagonal direction (direction of x) at the top of the slab:

$$s_c = \frac{3\,P}{h^2}\left[1-(a_1/l)^{0.6}\right] \qquad (5)$$

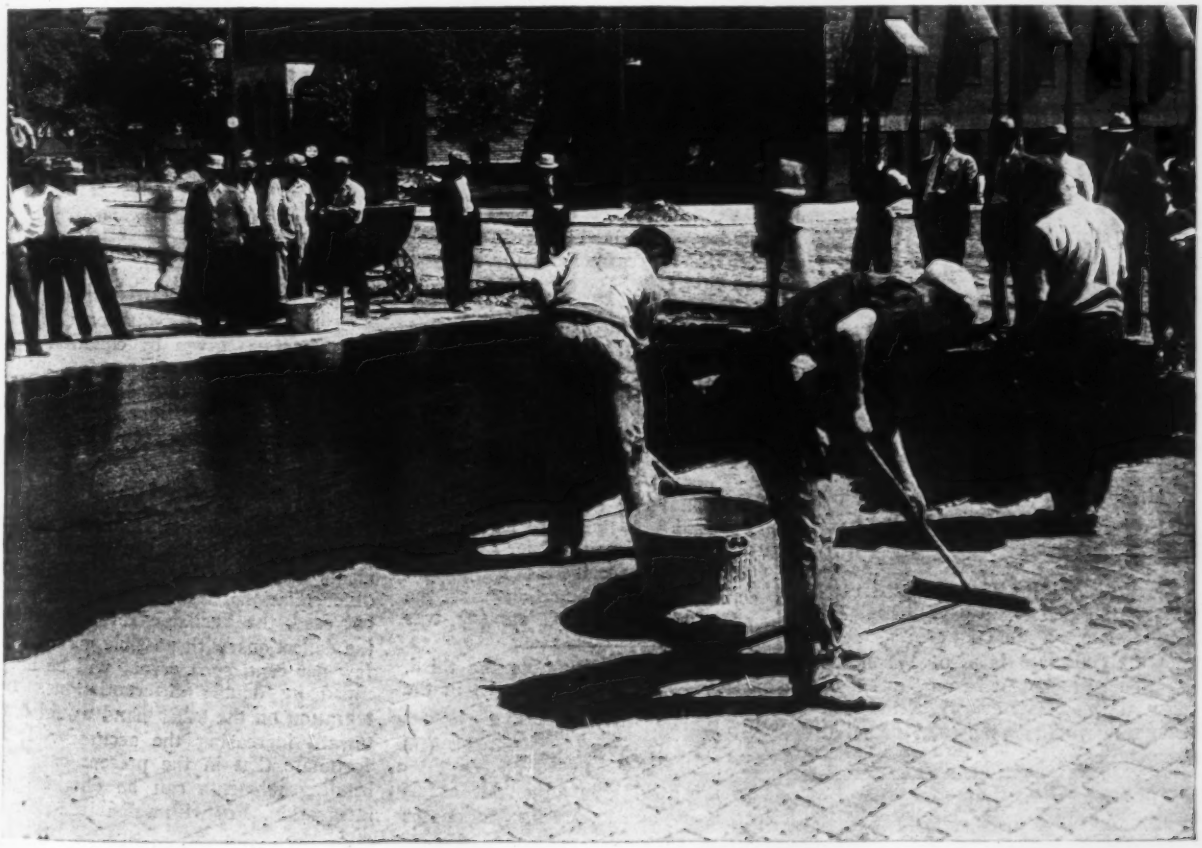
BRICK PAVEMENTS can be freed of excess bituminous filler material by advance coating with whitewash or similar materials that will facilitate peeling the excess filler off the surface.

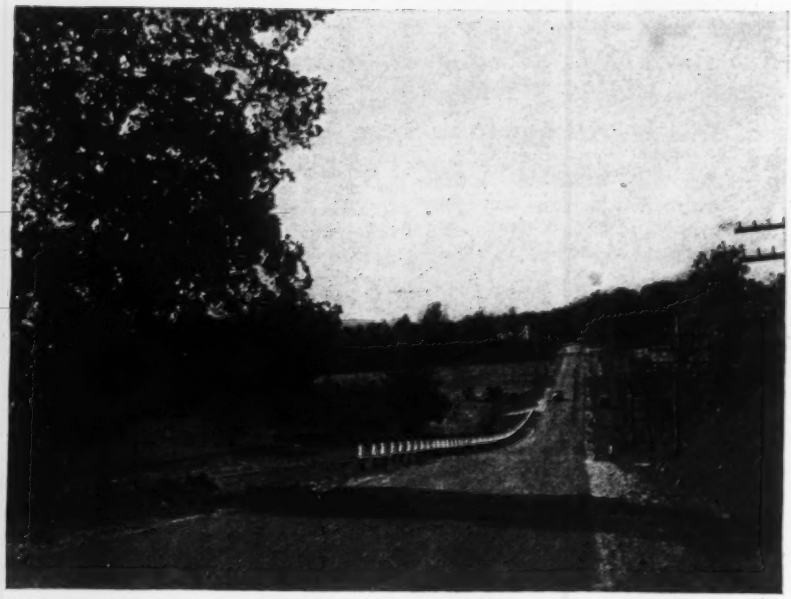
The paper referred to contains tables giving values of l and s_c for different values of k and h.

Derivation of formula

While the formulas and diagrams for loads at the edge and in the interior of the area were obtained by formal solution of the fourth-order partial differential equation governing the flexure of the slab (with approximations introduced in the final statement of the stresses), the formulas for the corner break, equations (3) to (5), were derived by a simple approximate process. An account of the various steps in this process has not been published previously. To prove that the process is simple and accessible, the first step of the analysis will be shown, and the remaining steps indicated.

The principle invoked is one of the principles of minimum of the potential energy; that of minimum by variation of the shape. If the potential energy is computed for all geometrically possible states of deformation, the true state of deformation can be picked out as that making the potential energy a minimum. The examination can be limited to plausible states of deformation. The first step is to make a guess of a simple function which contains an adjustable coefficient, and which may be expected to give a plausible picture of the distribution of the deflections if





STABLE SHOULDERS not only support the pavement but also invite the parking of cars off the travelled way.

the coefficient is adjusted properly.

The function

$$z = u\, e^{-x/l} \tag{6}$$

was chosen for this purpose, u being the adjustable coefficient, and x being measured as in Fig. 1. Equation (6) omits consideration of bending in the direction of y, but that influence can be considered in a later step. Equation (6) is plausible only for the first step. The energy stored in the slab by bending according to equation (6) is computed as

$$U_1 = \frac{1}{2}\int_0^\infty \left(-\frac{Eh^3 \cdot 2x}{12\,(1-\mu^2)}\,\frac{d^2z}{dx^2}\right)\left(-\frac{d^2z}{dx^2}\right)dx \tag{7}$$

The term μ^2 need not disturb anyone, since it is small. Substitution from equations (2) and (6) gives

$$U_1 = k\,u^2\int_0^\infty x\, e^{-2x/l}\,dx = \frac{kl^2u^2}{4} \tag{8}$$

The energy delivered to the subgrade becomes

$$U_2 = \frac{1}{2}\int_0^\infty (kz \cdot 2x\,dx)\,z \tag{9}$$

which gives

$$U_2 = U_1 \tag{10}$$

The load P is to be considered constant as the deflection progresses. Its potential energy can be taken as zero when the deflection is zero. When the deflection at the point of application of P is z, the potential energy of the load becomes—Pz. Thus the total potential energy becomes

$$E_p = \frac{kl^2}{2}u^2 - Pu\, e^{-a_1/l} \tag{11}$$

E_p becomes a minimum when

$$u = \frac{P}{kl^2}\,e^{-a_1/l} \tag{12}$$

The minimum thus obtained is only a relative minimum, because of the restricted form of equation (6), but actually this relative minimum is not very far from the true minimum, and accordingly a formula obtained from equations (6) and (12) will be a fair first approximation. One finds

$$z = \frac{P}{kl^2}\,e^{-(x+a_1)/l} \tag{13}$$

or, with a permissible approximation,

$$z = \frac{P}{kl^2}\,(1-a_1/l)\,e^{-x/l} \tag{14}$$

The deflections defined by equation (14) do not differ greatly from those given by equation (3).

As a second step, equation (6) may be modified by introducing one more adjustable coefficient, v, as follows:

$$z = u\, e^{-vx/l} \tag{15}$$

By varying both u and v one may expect to find a smaller relative minimum of the potential energy. When a_1 is small, one finds a value of v close to unity. This second step therefore leads to no material improvement over equation (14), but is nevertheless significant. It confirms the assumption that the choice of form of equation (6) was judicious.

The second step suggests the third, which is to write the deflection in the form

$$z = u_1 e^{-x/2l} + u_2 e^{-x/l} + u_3 e^{-2x/l} \tag{16}$$

There are now three adjustable coefficients, u_1, u_2, and u_3. By integrations as in equations (7) to (9) the potential energy stored in the slab and the subgrade is found to be

$$U_1 + U_2 = kl^2\left[\frac{17}{16}u_1^2 + \frac{10}{9}u_1u_2 + \frac{16}{25}u_1u_3 + \frac{1}{2}u_2^2 + \frac{10}{9}u_2u_3 + \frac{17}{16}u_3^2\right] \tag{17}$$

The condition of minimum of the total potential energy, including that of the load, gives three linear equations for u_1, u_2, and u_3. Solution of these three equations in the two cases $a_1 = 0$ and $a_1 = l/10$, led to the following solution, applicable in these two cases, and approximately applicable for other values of a_1:

$$z = \frac{P}{kl^2}\left[-0.375\,e^{-x/2l} + 1.834\,e^{-x/l} - 0.375\,e^{-2x/l} - \frac{a_1}{l}\left(-0.133\,e^{-x/2l} + 0.255\,e^{-x/l} + 0.760\,e^{-2x/l}\right)\right] \tag{18}$$

When a_1 and l are within the plausible ranges, the results in equation (18) are represented with satisfactory accuracy by equation (3).

It is not sufficient merely to arrive at equation (3). A fourth step is required to confirm it. It is necessary to investigate whether consideration of the bending in the direction of y and twisting in the directions of x and y will bring about appreciable modifications. For this reason a minimum of potential energy was established for a solution of the type

$$z = u_1 \cos\frac{u_2 y}{l}\, e^{-u_2u_3\,x/l} \tag{19}$$

by adjusting the three coefficients u_1, u_2, and u_3. With Poisson's ratio = 0.15, the following solution was found to give minimum of energy when $a_1 = 0$ and $a_1 = l/10$, and it will apply approximately for other values of a_1:

$$z = \frac{P}{kl^2}\left[1.094\cos\frac{0.541\,y}{l}\,e^{-0.983\,x/l} - 0.922\,\frac{a}{l}\cos\frac{y}{1.1l}\,e^{-2x/l}\right] \tag{20}$$

The values defined by equation (20) are close to those given by equation (3). If one can depend on a constant modulus of subgrade reaction k, equation (3) will define the deflections near the corner with satisfactory accuracy.

Stresses near corner

If an exact formula for the deflections were available, the bending moments could be determined by double differentiations, but if, as in the present case, the available formula defines the deflections with possible errors of a few per cent, such errors will be magnified by double differentiations. Integration on the other hand would tend toward increasing the accuracy. It is fortunate that in the present case the bending moments can be obtained by integration. For with a definite modulus

of subgrade reaction k, when the deflections are known, the reactions are known, and the bending moments and the corresponding stresses can be computed by integration. After tabulating numerical values of the maximum stresses, it was found that these stresses would be represented with satisfactory accuracy by equation (5). These computations also led to equation (4), which defines the distance to the point of maximum stress roughly.

Daily changes of temperature cause the slabs to rise at the middle on warm afternoons and at the edges and corners during cool nights.* It is conceivable therefore that during cool nights or mornings the part near the corner may lose contact with the subgrade. The same effect may be produced by escape of the subgrade under repeated working of the relatively great deflections that are possible at corners.

For these reasons it appears desirable to investigate the particular case suggested in Fig. 1: the contact is assumed missing within the triangular area where $x < b_1$. An estimate is needed of the influence of the missing reaction. Equations (3) to (5) lend themselves to this purpose. For small values of x equation (3) may be written in the simplified form

$$z = \frac{P}{kl^2}\,(1.1 - 0.9(a_1 + x)/l) \qquad (21)$$

The scheme is to compute by equation (21) as if the subgrade gave full support, but to compensate by introducing the missing reaction as an additional downward force. This force Q can be considered, without serious error, as a force acting at the center of gravity of the unsupported area, at the point $x = 2b_1/3$. Equation (21) gives the following deflections at this point: From the wheel load P alone:

$$z_1 = \frac{P}{kl^2}\,(1.1 - 0.9\,a_1/l - 0.6\,b_1/l) \qquad (22)$$

From the missing reaction $-Q$ alone:

$$z_2 = \frac{Q}{kl^2}\,(1.1 - 1.2b_1/l) \qquad (23)$$

Since the size of the unsupported area is b_1^2, the value of the missing reaction may be computed approximately as

$$Q = k(z_1 + z_2)\,b_1^2 \qquad (24)$$

Eliminating z_1 and z_2 from equations (22) to (24), one finds

$$Q = \frac{P(1.1 - 0.9\,a_1/l - 0.6\,b_1/l)}{(l/b_1)^2 - 1.1 + 1.2\,b_1/l} \qquad (25)$$

After computing the value of Q the maximum stress due to Q may be obtained from equation (5) by replacing P by Q and a_1 by $2b_1/3$. The maximum stresses from P and Q do not ordinarily occur at the same point, but when b_1 is small enough to permit the application of this analysis, the sum of the two maximum stresses will be a suitable estimate of the resultant maximum stress.

A numerical example will suggest the order of magnitude of the quantities involved. Let $h = 7$ in., $k = 100$ lb.in.$^{-3}$, $E = 3{,}000{,}000$ lb.in.$^{-2}$, $\mu = 0.15$, $P = 10{,}000$ lb., $a = 4$ in., $b = 18$ in. Then $a_1 = 4\sqrt{2}$ in., $b_1 = 9\sqrt{2}$ in. Equation (2) gives $l = 30.6$ in. (this value may also be taken from Table 1 in the paper in "Public Roads", April, 1926). By substituting these values in equation (25) one finds $Q = 1320$ lb. One may stop the computations here. For the significant indication has been obtained that the deflections and stresses will be increased not more than about thirteen per cent. But if desired, one may compute the maximum stresses by equation (5) (or by use of Table 2 in the paper in "Public Roads", April, 1926). One finds: From P, $s_e = 390$ lb.in.$^{-2}$; from Q, $s_e = 0.132 \cdot 329$ lb.in.$^{-2} = 43$ lb.in.$^{-2}$; resultant stress $s_e = 433$ lb.in.$^{-2}$; that is, an increase of eleven per cent.

The fifth article in the current series of papers by L. W. Teller and Earl C. Sutherland in "Public Roads" is yet to appear, and may be expected to report experimental data relating to the corner break. The computations that have just been shown may possibly serve a purpose in helping to interpret these new data, which may be expected to be significant because of the skill and care with which these tests are known to have been conducted.

The following approximate formulas are quoted from the paper in "Public Roads," April, 1926. The formulas were derived for the case of uniform thickness h; they confirm the observation that a thickened edge is needed. Poisson's ratio was taken as 0.15.

Load P at the edge, at a considerable distance from any corner, distributed uniformly over the area of a small semi-circle with radius a and with the center on the edge; tensile stress at the bottom:

$$s_e = 0.572\,\frac{P}{h^2}\left[\log_{10}(h^3) - 4\log_{10}(\sqrt{1.6a^2 + h^2} - 0.675\,h) - \log_{10}k + 5.767\right] \qquad (26)$$

Load P at a point of the interior of the area, at a considerable distance from any edge, distributed uniformly over the area of a small circle with radius a; tensile stress at the bottom:

$$s = 0.3162\,\frac{P}{h^2}\left[\log_{10}(h^3) - 4\log_{10}(\sqrt{1.6a^2 + h^2} - 0.675\,h) - \log_{10}k + 6.478\right] \qquad (27)$$

The same paper contains diagrams of deflections and bending moments, by means of which one may compute the rather small increases of stress caused by neighboring loads, for example in the case of two trucks passing each other.

Coefficient of subgrade stiffness

In a paper in "Public Roads," December, 1933, the writer suggested the possibility of using a "coefficient of subgrade stiffness," K, defined as

$$K = kl \qquad (28)$$

instead of the modulus k, as a measure of the resistance of the subgrade, the thought being that K might be found more nearly uniform than k. The values $k = 100$ lb.in.$^{-3}$, $l = 30$ in. would give $K = 3000$ lb.in.$^{-2}$. It is noted that K is measurable in pounds per square inch. Equations (26) and (27) assume slightly simpler forms when restated in terms of K. Also the use of K lends itself to revisions in the statement of the distribution of the reactions from the subgrade. Whether this suggestion is profitable remains to be seen. Scrutiny in the light of the results of tests would be required.

WIDER USE OF MACHINES in maintenance has resulted in greater uniformity of surface and longer life for the pavement.

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January 7, 1937

ENGINEERING NEWS-RECORD is a consolidation of Engineering News and Engineering Record, effected in 1917. The Contractor was consolidated with Engineering News Record in 1918. Engineering News was founded in 1874 as The Engineer and Surveyor, which title subsequently became The Engineer, Architect and Surveyor. Engineering News and American Railway Journal and finally Engineering News. Engineering Record was established in 1877 as The Plumber and Sanitary Engineer. The name was subsequently changed to The Sanitary Engineer, Engineering and Building Record, and, finally, to Engineering Record.

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Grade-Crossing Work Goes On

WITHOUT telling anything essentially new, the announcement of federal-aid allocations by the Bureau of Public Roads brings a reminder that the grade-crossing elimination program started last year will continue. Much has been accomplished through the first year's appropriation, though progress by now would be much larger had the administration three years ago recognized the great employment-relief possibilities of a comprehensive grade-crossing campaign. Under the terms of the Hayden-Cartwright act the improvement of railroad grade crossings will continue at least for two more years, and there is reasonable hope that by that time the merits of the undertaking will be so convincingly evident that its continuation will be assured. Every crossing of a busy railroad main line over a highway trunkline should be separated before the work is allowed to stop.

A New Year's Wish

IF WE COULD HAVE A WISH for the new year it would be this: that safety might be made the guiding star of all construction. We would like to see the whole industry turn safety-minded. We would like to see accidents reduced to negligible proportions, and this not by luck but by forethought and trained caution. There are many safety-minded men in construction, but not enough; the list should include every contractor, every superintendent and foreman, every single worker on the job—and every engineer who specifies operating conditions or supervises them in the field. At Grand Coulee the contractors painted on the rock face of the abutment the legend "Safety First", in giant letters that can be seen from every part of the site; this action expresses the ideal that ought to animate every job and every worker, until construction makes its record as good as that of other industries no less hazardous. We still have to learn that safety does not mean slower progress, and that it does not cost money. But it does cost thought and care, and a will to make it the first rule of operation.

Guidance for the Young

A NEW FORM OF GUIDANCE for prospective entrants to engineering study is being tried by the Iowa Engineering Society. The method adopted is to call for prize essays on engineering by high-school students throughout the state, with a view to bringing the facts of the engineering career to the attention of parents, teachers and the students themselves. The inception of the plan is due to a general feeling within the society that the profession is not as well understood by laymen as are the medical and legal professions, and that the fault lies in failure to develop proper public relations. Others will agree with the Iowa engineers that the public could and should have a better understanding of the engineer's part in the community. The Iowa plan is well worth trying, provided it is consistently handled as a means of guidance rather than a means of propaganda. Of course it can easily degenerate into something like a toothbrush manufacturer's slogan contest. There is obvious danger that the plan may work out as a whoop-it-up campaign; but if carried through in the right spirit and with the right cooperation from engineers in practice, it should avoid this danger and produce constructive results.

Why Do They Do It?

ONE OF THE THINGS that complicates local government needlessly is illustrated by a Chicago incident. For more than a dozen years a streetcar company has persisted in maintaining tracks on temporary permit across and along a park boulevard, against strenuous objection on the part of the authorities and civic administrators, though the cars that ran on these tracks never carried much traffic. Now at last the state commerce commission has ordered the tracks removed, for lack of "convenience and necessity". The long effort to get the tracks off the boulevard has cost the public large sums of money in legal and engineering charges; thousands of pages of testimony and scores of engineering exhibits went into the hearing record. All this because the company insisted on defending a questionable right and maintaining a service of doubtful value against the desire of the public. It is fortunate that the crossing is at last to be removed, for lying at the foot of the north approach of the new Outer Drive bridge it would create a serious traffic obstruction and hazard. Perhaps no one thing that the streetcar officials ever did has been more resented or has lost them so much public sympathy as their dog-in-the-manger attitude on these particular tracks. Why they did not long ago appreciate that it is bad business to arouse public antagonism and bad feeling in this way is one of the mysteries of modern business life—the more so as the company, whose lines are operated only on day-to-day franchise extensions, needs every ounce of good will that a sound public-relations policy can build up.

Continued Subsidy Demanded

A NEW ARGUMENT is injected into the current discussion of whether the WPA work-relief system should be continued, by the demand of city mayors that the federal government continue to care for the able-bodied unemployed. It is distinctly a new argument. Ever since the winter of 1933, when the federal government volunteered to take over part of the job of carrying the unemployed through, there have been occasional suggestions that caring for unemployment is a federal and not a local responsibility; but we believe that this doctrine was never definitely asserted by any important group until the report of the Conference of Mayors a few days ago. The mayors say that they are willing to care for persons incapacitated for work, but that the federal government has the duty of providing for the able-bodied. A significant point of their statement

is the admission that they are talking not of an emergency but of a normal and continuing condition. Again, they avoid saying that the cities are financially unable to take care of unemployment. In short, the mayors' demand amounts to a call for a permanent federal subsidy to cities. Such financing would be the longest step yet made toward federalization of local affairs, which inevitably suggests the question how soon Washington may have to participate also in city administration.

New Blood

RECENT CONTACT with a number of municipalities reveals that a salutary change has taken place within the past few years, one that augurs well for better public service. Personnel changes resulting from the depression have brought into public administration a number of exceptionally qualified men new to public service but able to bring to it broad view and capacity. Examples: a banker who became city director of finance, a consulting engineer serving as city engineer, an experienced contractor directing public works. In each case the community has profited by this accession of specially trained men to its administrative work. Their skill as well as their ability to organize departmental activities for greater efficiency and economy promises lasting benefit. More careful financial control, better record-keeping and accounting and revamped maintenance and improvement procedures are among the results of their work. It is not likely that the taxpayers will quietly tolerate a return to less efficient local government methods.

Progress and More Progress

SURPRISING FIGURES emerge from the summing up of construction reports for the year just closed. The nation's total, estimated last January as likely to reach 4½ billion dollars, actually amounts to nearly 6 billions—5.6, to be exact. This compares with something less than 4 billions for 1935, and thus represents an increase of more than half. The unexpected growth suggests rather clearly that we are at the start of a new era of big construction.

All the background factors reveal solid strength, the labor factor for the moment excepted. As tersely summarized in a year-end statement of Commerce Secretary Roper last week:

> Business activity was at the highest point since 1930; it is still tending upward. The production of industrial commodities was substantially higher than in 1935; the income of the farm population further improved; employment and payrolls sustained their upward movement; enhanced consumer purchasing power was reflected in an expansion in retail sales; conditions in the railroad industry improved materially; our foreign trade expanded further. The construction industry, where the effects of the depression have been extremely severe, experienced a sustained advance.

The sober terms of the official statement hardly do the year's performance justice; but the facts emphasize sufficiently the unanimity with which all parts of the business economy join in the advance. This very unanimity provides a solid base for forecasting, since construction, itself a powerful stimulant to industry, business and employment, cannot fail to thrive when confidence and money are at hand and when industry is producing actively and trade is busy. For 1937 we may well look forward to a minimum of 7 billions of construction.

Expressing the record in terms of effect on the nation as a whole: Last year's construction increase was responsible for the reemployment of more than 1½ million men, and 1937 should put another million to work. In addition the coming year will enlarge the market for materials and supplies by more than half a billion dollars, and here as well as in the secondary services at least another million persons will find new employment.

That, briefly put, is the fair promise of present conditions. As said above, labor unrest is the only cloud on the horizon. Its scope and ultimate effect cannot yet be judged, but the average man's practical common sense is apt to turn the scale and leave the growth of prosperity to proceed undisturbed.

Safer and Better Roads

FULL CONSIDERATION of the able appraisal of highway engineering problems that forms the contents of this issue reveals a condition both favorable and unfavorable. The high standards of the art with respect to both structure and operating service of the road are evidence of excellent progress. The dark side of the picture, however, is that these standards, especially those for plan and detail location, are often violated. The spread between what we should build and what we do build is unjustifiably large.

Practices are tolerated that are far below what is recognized as best; frequent departure from standard is considered permissible merely because it happens to be convenient by reason of topography or old location. The limits of toleration are so wide, in fact, that the carefully developed standards of the art largely are dead letters. And this failure produces roads that, after a safe and capacious mile or two, lead traffic into unsuspected bottlenecks and death traps. Such conditions play a part in the bad safety record and low service efficiency of our present-day highway network.

If we would build better roads, the first step obviously is to end the practice of violating the standards of efficient operating service. These standards, however imperfect and however subject to later improvement, are for the present the best available statement of *necessary* practice—not of superpractice but of practice regularly required to suit traffic conditions. The standards are rules to be followed strictly, without exception save in compelling emergency. If we will write "must" in place of "should" in the rules for roadway width, for sight distance, for superelevation, for curvature, shoulder width and surface, we can quickly build up a more efficient and a safer transportation system.

Elementary though it be, let us keep in mind that roads exist solely to carry traffic, and that everything we do about roads is subject to the test of how well it adapts them to safe and efficient traffic service. Traffic requires roadway room, curves and grades over which it can move rapidly, conveniently and safely. Alignment, profile and cross-section are not academic ideals, but have intensely practical meaning as factors that contribute to transportation efficiency and to easy and perfect maintenance.

The best road standards of today are well devised for this service. But standards alone are not sufficient; they must be applied before they are of use. And when we do apply them, consistently and determinedly, we will have safer and better roads than can be found today.

CURRENT NEWS

War Department's 1938 Projects

Engineers recommend $140,000,000 for rivers and harbors and $113,000,000 for flood control work

The annual report of the Corps of Engineers lists new construction projects costing $140,150,000 on which money can be profitably expended during the fiscal year beginning July 1, 1937. It further recommends flood-control projects costing $112,646,000.

An expenditure of $39,717,000 is recommended for maintenance of rivers and harbors and an expenditure of $1,800 for maintenance of flood control work.

Flood control

The following flood-control projects were recommended in the report:

Mississippi River and tributaries	$55,000,000
Emergency Work on Mississippi Tributaries	300,000
Sacramento River, Calif.	814,000
Projects authorized in the Omnibus flood control act	56,532,000
TOTAL	$112,646,000

Rivers and harbors

The following is a list of the larger projects for new work on rivers and harbors:

Cape Cod Canal, Mass.	$4,000,000
New York Harbor	1,200,000
Great Lakes to Hudson River waterway	10,000,000
New York and New Jersey Channel	5,000,000
Chespeake and Delaware Canal	3,650,000
Caloosahatchee River and Lake Okeechobee drainage area, Fla.	1,000,000
Black Warrior, and Tom Bigbee Rivers, Ala.	1,684,000
Sabine-Natchez waterway, Texas	1,090,000
Louisiana-Texas Intracoastal waterway (Sabine River-Corpus Christi Section)	1,900,000
Houston Ship Channel, Texas	1,500,000
Mississippi River between the Ohio and the Missouri Rivers	1,000,000
Mississippi River between the Missouri River and Minneapolis	35,041,000
Illinois Waterway	7,934,000
Missouri River, Kansas City to Sioux City	18,600,000
Missouri River at Fort Peck	8,706,000
Ohio River	1,050,000
Kanawha River, West Virginia	2,480,000
Keweenah Waterway, Michigan	1,600,000
Los Angeles and Long Beach Harbor, California	1,375,000
Sacramento River debris control	4,645,000
Bonneville Dam	6,974,000
Grays Harbor and Chehalis River, Washington	1,620,000
TOTAL	$149,050,000

Queens Extension Opened On New York Subway

A 3½-mile addition to the Queens branch of the municipally owned New York City Independent Subway System which extends the line from Roosevelt Ave. in Jackson Heights, Queens, to a new terminus in Kew Gardens, Queens, was opened to traffic on Dec. 31.

BONNEVILLE AT NIGHT

THIS night photo at Bonneville dam shows the nearly completed south half of the main spillway. The spillway as a whole is now about 60 per cent complete; the locks are 88 per cent finished; the power house 80 per cent; and the fishways 54 per cent. With the entire project about 70 per cent completed, it is estimated that the dam will be finished by the end of this year. Work started in October, 1933.

TVA Appeals Injunction Order

The Tennessee Valley Authority on Dec. 30 formally appealed from the injunction issued against its further expansion by the U. S. district court for middle Tennessee (*ENR*, Dec. 17, 1936, p. 874). The appeal will be taken to the U. S. circuit court of appeals at Cincinnati.

A review will be requested not only of the injunction order but also of the lower court's ruling that it had jurisdiction in the case.

Colorado to Check Pollution Of Streams Within the State

State sanitary engineer B. V. Howe of the Colorado state board of health has notified municipalities and industries in the state that the hitherto unenforced 1931 law prohibiting pollution of streams will soon be rigidly enforced. Notice that they must build sewage disposal plants has been served on cities throughout the state which are not already so equipped, and the board of health has assured city councils that if they do not comply within a reasonable time they will be prosecuted.

Likewise the beet sugar companies of Colorado have been informed that they will be required to treat their industrial wastes as soon as communities conform to state requirements by properly treating their domestic sewage. Mining mills and smelters will also be forced to discontinue emptying refuse into the stream.

State institutions have been informed that they will be required to treat their sewage, and detailed estimates of the cost of plants to treat sewage from the state penitentiary at Canon City and the state home for mental defectives at Ridge have been supplied. Funds for sewage treatment have been included in the budgets of these institutions and of the state hospital for the insane at Pueblo.

Pollution is especially bad in the Arkansas River, according to sanitary engineer Howe, who states: "The pollution load from Pueblo to the Arkansas River is greater than all others combined that contribute to this river. There are 300,000 acres of land irrigated by the Arkansas River below Pueblo which also provides the municipal water supply to Rocky Forge through the Catlin Canal. Sixteen thousand acres of vegetables and fruits are irrigated with this sewage-laden water from the Arkansas River. The state laws provide that no domestic sewage nor water containing domestic sewage in amount and condition such that bacteria of the Coli-aerogenes group are present in quantities of ten or more per c.c. shall be used to irrigate or be permitted to overflow any fruits or vegetables for human consumption, the edible portions of which grow in the ground or above it within one foot of the surface, except with the written permission of the state board of health."

Mr. Howe stated that the average annual death rate of children under two years from diarrhea and enteritis of all the Arkansas River counties is 38.1 per 1,000 births, while the river counties above Pueblo has a corresponding death rate of only 18.4 per 1,000 births.

I.C.C. Issues Safety Rules for Motor Vehicles on Highways

Acting under the authority granted it to regulate interstate commerce by motor carriers, the Interstate Commerce Commission has issued the first federal rules and regulations in the field of highway safety governing the equipment and personnel engaged in such commerce as common carriers or contract carriers and laying down general operating rules for the protection of the public.

In issuing the new regulations the commission emphasizes that its work is by no means complete. Because of the wide variation in state regulations and the lack of agreement on the value of many requirements, the commission has confined its initial rules to basic generalities. Its guiding motives so far are to make clear the broad scope of the program of safety regulations that it intends to follow; to select for immediate attention certain important items expected to improve definitely the safety of operation of a large portion of the carriers without hampering further voluntary advancement on the part of state officials and operators; and to set forth these initial regulations in general terms which may be supplemented and strengthened by later elaboration.

The regulations now promulgated lay down rules for the qualifications of drivers, rules governing driving, rules for the equipment of vehicles, and rules on the reporting of accidents. The first three of these classifications become effective July 1, 1937, and accident reporting must be started April 1, 1937.

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Contractor Asks Refund On Gasoline Tax Payment

The Mason-Walsh-Atkinson-Kier Co., Grand Coulee dam contractors, have started action in the Washington state court at Olympia to recover $14,000 in state gasoline taxes paid on gas used in oversized trucks not operating on state or county highways.

The company contends it is entitled to a refund because the trucks using the gasoline are too heavy to be allowed on state or county highways. It holds further that the state annually pays out more than a million dollars in gas tax refunds to farmers, mariners, and others using gasoline in vehicles or boats not operating on highways.

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Power Body Denies License To Missouri Project

The Federal Power Commission has denied an application of the Current River Power Co., Kansas City, Mo., for a license for a hydro-electric project to be located on the Current River in the counties of Carter, Ripley, and Shannon in Missouri. The application was denied because the applicant failed to show ability to finance the proposal and failed to show a market for the power to be developed by the project.

The project was to consist of three developments. The Hargus Eddy development consisted of a dam at Hargus Eddy, 60.3 miles above the mouth of Current River, an 8,760-acre reservoir with a storage capacity of about 147,000 acre-ft. and a 60,000-hp. power plant. The Mill Creek development consisted of a dam just below the mouth of Mill Creek, 97.5 miles above the mouth of the Current River, an 87,000-acre-ft. reservoir, and a 30,000-hp. power plant. The Blair Creek development included a dam below the mouth of Blair Creek, 121 miles above the mouth of Current River, a 125,000-acre-ft. reservoir, and a 17,000-hp. plant.

The power commission has deferred action, at the request of the applicant, on an application for an extension of time for completion of the Santee-Cooper project on the Santee and Cooper Rivers in South Carolina until Feb. 28, 1937. The license, which is now held by the Columbia Railway & Navigation Co., calls for completion of the initial installation of the project on Dec. 31, 1936. The licensee had applied to the commission for an extension of time to such date not earlier than Dec. 31, 1939 as the commission might find reasonable, and has now requested that action be deferred until Feb. 28.

The Columbia company has entered into a contract with the South Carolina Public Service Authority for the transfer to the Authority of the license and the purchase by the Authority of all lands, water rights, easements, franchises, engineering data and construction plans prepared for the development of the project. This contract terminates Feb. 28, 1937. Full performance of the contract between the two agencies has thus far been prevented by pending litigation against the Authority.

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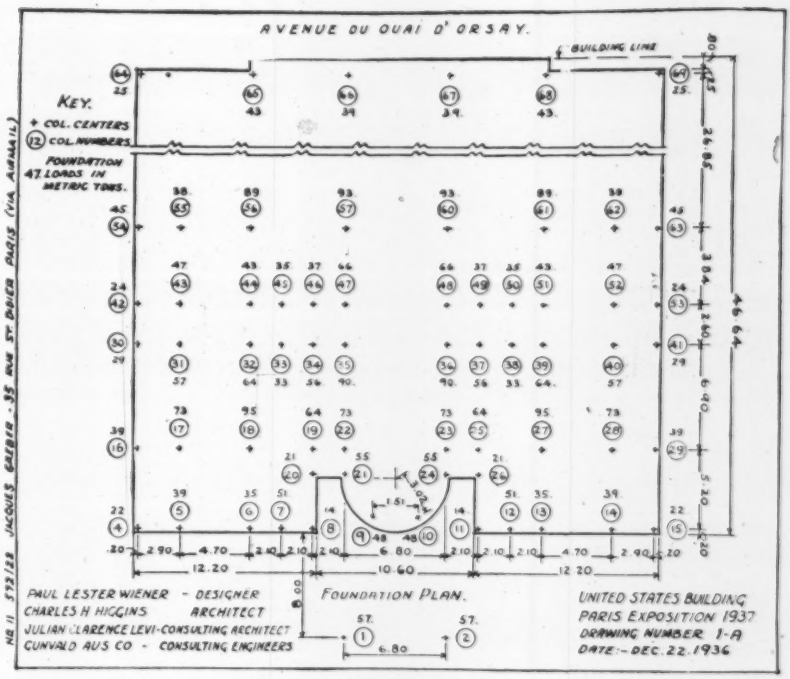
Seattle Decides to Use Gravity Dam

The $4,380,000 Ruby dam on the Skagit River, for which bids will shortly be asked by the city of Seattle, Wash., will be built as a gravity dam, according to a decision reached by Seattle city light officials. A combination of the constant angle arch dam and the gravity dam had been planned originally. The lighting department's present decision is subject to review and approval by the Federal Power Commission.

A contract for diamond drilling at the dam site has already been awarded, and bids will be opened Jan. 14 for clearing the basin behind the dam. The city has also awarded several contracts for material to be used in the construction of foundations for a 150 mile transmission line which will bring power from the dam to the city.



FIRST RADIO TRANSMISSION OF BUILDING PLANS

THIS FOUNDATION layout is believed to be the first building plan ever to be transmitted by radio. It shows the column layout of the American building at the 1937 Paris World's Fair. The plan was transmitted from New York, from the facsimile transmission office of RCA Communications, to London and thence to Paris by airplane. The transmission took less than an hour.

The American Exposition Building is a steel, glass, and concrete structure containing a large exposition hall and a five-story tower. It will be prefabricated in this country and the parts shipped to Paris for assembly. The building will stand over the tracks of the Paris subway, and the foundations and columns on which it will stand are being built by and at the expense of the French government. The building will cost about $200,000.

It is stated that the necessity for speed in sending the plans arose from the fact that it was desired to start work on the foundations before the annual overflow of the Seine, on the banks of which the building will stand.

Highway Funds Allotted to States

$200,000,000 fund includes $25,000,000 for secondary roads and $50,000,000 for crossing elimination

The Secretary of Agriculture on Dec. 29 announced the apportionment to the states of $200,000,000 of federal-aid highway funds. Of this sum $125,000,000 is the regular federal aid for improvement of the federal-aid highway system. An additional $25,000,000 is provided for the improvement of secondary or farm-to-market roads, and $50,000,000 is provided for the elimination of rail-highway grade crossings. The new apportionments are for the fiscal year beginning July 1, 1937.

These funds will be administered in the same manner as has been used in previous federal-aid highway work. Projects will be selected by the state highway department, which will also prepare the plans, let contracts, and supervise construction, all subject to federal approval.

The states are required to match the funds for improvement of the federal-aid system and for secondary roads. Funds for use on the federal-aid system are now available for improving extensions of the system through cities.

It is not required that the grade crossing funds be matched.

Improvements to secondary roads and elimination of grade crossings with federal funds were first begun as emergency measures to relieve unemployment. The present apportionment of funds for these purposes is the first to be made as part of the regular federal program. Regulations under which the new funds will be administered are now being prepared.

The accompanying table shows the detailed apportionment by states and territories.

At the same time a further apportionment of $2,500,000 was made for the construction of main roads through unappropriated or unreserved public lands, nontaxable Indian lands, or other federal reservations other than national forests during the year 1938. Authorization for this class of work was first made in 1930, and the new apportionment brings the total funds apportioned to date to $17,500,000. Previous authorization provided for the construction of more than 1,400 miles of road.

APPORTIONMENT OF FEDERAL-AID HIGHWAY FUNDS

State	Regular Federal Aid	Secondary or Feeder Roads	Grade Crossings	Total
Alabama	$2,664,693	$532,939	$1,015,170	$4,212,802
Arizona	1,829,952	365,990	314,594	2,510,536
Arkansas	2,187,752	437,550	893,403	3,518,705
California	4,858,220	971,644	1,874,656	7,704,520
Colorado	2,336,054	467,211	657,357	3,460,622
Connecticut	805,426	161,085	426,784	1,393,295
Delaware	625,000	125,000	250,000	1,000,000
Florida	1,704,765	340,953	712,816	2,758,534
Georgia	3,233,279	646,656	1,223,099	5,103,034
Idaho	1,570,687	314,137	418,115	2,302,939
Illinois	5,238,798	1,047,760	2,644,980	8,931,538
Indiana	3,149,011	629,802	1,308,113	5,086,926
Iowa	3,291,322	658,264	1,410,787	5,360,373
Kansas	3,374,126	674,825	1,307,669	5,356,620
Kentucky	2,349,316	469,863	919,174	3,738,353
Louisiana	1,829,490	365,898	799,226	2,994,614
Maine	1,122,670	224,534	352,468	1,699,672
Maryland	1,043,938	208,787	519,993	1,772,718
Massachusetts	1,769,936	353,987	1,047,500	3,171,423
Michigan	3,893,528	778,706	1,664,807	6,337,041
Minnesota	3,495,178	699,036	1,342,809	5,537,023
Mississippi	2,247,708	449,542	806,707	3,503,957
Missouri	3,877,890	775,578	1,528,920	6,182,388
Montana	2,621,728	524,346	671,204	3,817,278
Nebraska	2,641,423	528,285	892,976	4,062,684
Nevada	1,632,385	326,477	250,000	2,208,862
New Hampshire	625,000	125,000	250,000	1,000,000
New Jersey	1,701,826	340,365	997,689	3,039,880
New Mexico	2,040,685	408,137	432,291	2,881,113
New York	6,258,857	1,251,771	3,424,399	10,935,027
North Carolina	2,998,371	599,674	1,244,662	4,842,707
North Dakota	1,996,414	399,283	803,068	3,198,765
Ohio	4,640,344	928,069	2,141,704	7,710,117
Oklahoma	2,995,620	599,124	1,156,175	4,750,919
Oregon	2,092,368	418,474	588,377	3,099,219
Pennsylvania	5,434,356	1,086,871	2,905,671	9,426,898
Rhode Island	625,000	125,000	250,000	1,000,000
South Carolina	1,722,188	344,438	752,928	2,819,554
South Dakota	2,084,100	416,820	694,096	3,195,016
Tennessee	2,681,110	536,222	958,753	4,176,085
Texas	7,957,610	1,591,522	2,724,825	12,273,957
Utah	1,447,780	289,556	322,885	2,060,221
Vermont	625,000	125,000	250,000	1,000,000
Virginia	2,328,369	465,674	941,656	3,735,699
Washington	2,002,877	400,575	767,991	3,171,443
West Virginia	1,390,447	278,089	671,712	2,340,248
Wisconsin	3,107,053	621,411	1,252,871	4,981,335
Wyoming	1,600,350	320,070	344,961	2,265,381
Dist. of Col	.....	.....	250,000	250,000
Hawaii	625,000	125,000	250,000	1,000,000
Puerto Rico	625,000	125,000	369,959	1,119,959
Total	$125,000,000	$25,000,000	$50,000,000	$200,000,000

TVA Wages Raised

Substantial raises in pay for many employees of the Tennessee Valley Authority went into effect on Jan. 1. Hourly wage employees received a new scale agreed upon by negotiation between representatives of TVA and of the workers. Salaried workers have been graded into three classes, unsatisfactory, satisfactory, or very satisfactory. The first rating results in dismissal, demotion, or transfer to a different type of work. The second brings a pay increase, and the third a double pay increase.

The size of the raises are governed by the present salary scale. For those receiving up to $1260, it is $150; to $1800, it is $180; to $3500; it is $300; to $5600, it is $400; and above $5600, it is $500. All TVA employes are eligible for this increase, except the three directors whose $10,000 salaries are fixed by law.

Engineer Appointed to Head Louisiana Commission

J. Lester White of Bastrop, La., has been named full-time chairman of the Louisiana State Planning Commission, created by the 1936 legislature (*ENR*, July 23, 1936, p. 135). The commission will employ a secretary and draftsman and will start work immediately in coordinating all PWA and WPA work now being done in Louisiana. Under the terms of the act creating the commission, all plans for public buildings, improvements affecting highway locations, and other publicly financed work must be passed upon by the commission.

Mr. White is a graduate in civil engineering from Louisiana State University Engineering College, and has been for fourteen years engineer for the parish of Morehouse.

Dr. Paul Hebert, dean of Louisiana State University, was appointed a member of the commission representing the University. Ex officio members of the commission include: L. B. Abernathy, Louisiana highway commission, chairman; W. G. Rankin, Louisiana Conservation Commission; Dr. J. A. O'Hara, president, Louisiana State Board of Health; Harry D. Wilson, Louisiana Commissioner of Agriculture; and Harry Jacobs, chief of the Louisiana State Board of Engineers.

Big Irrigation Project Finished in India

The Lloyd Barrage at Sukkur, India, a 6,500,000-acre irrigation project was completed recently. The barage, equipped with sluice gates and regulators, has a length of 4,600 ft. Seven main canals of the irrigation system radiate from the site. The total length of main line canals and branches is 1,600 miles, and there are 4,622 miles of distributing canals.

Construction of the barrage and canal system involved about 210,000,000 cu.yd. of excavation.

Concrete Contractors Will Meet in Chicago

A National Concrete Contractors Conference will be held in Chicago on Jan. 18-20. The program will include technical discussions of modern concrete construction practices and also the advertising and promotional aspects of contracting.

At the same time that the Concrete Contractors Conference is held, four other groups of concrete users will hold their conventions simultaneously. The National Concrete Masonry Association, the Cast Stone Institute, the American Concrete Pipe Association, and the National Cinder Concrete Products Association have planned their meetings at the same time. Several joint sessions have been scheduled. A large exhibit of concrete machinery, accessories, and materials will also be a feature.

SOCIETY CALENDAR

ASSOCIATED EQUIPMENT DISTRIBUTORS, annual meeting, New Orleans, La., Jan. 10-12.

CANADIAN CONSTRUCTION ASSOCIATION, annual convention, Ottawa, Canada, Jan. 11-13.

AMERICAN ROAD BUILDERS ASSOCIATION, convention and highway exhibit, New Orleans, La., Jan. 11-15.

UNIVERSITY OF COLORADO, highway engineering conference, Boulder, Colo., Jan. 14-15.

AMERICAN ENGINEERING COUNCIL, annual assembly, Washington, D. C., Jan. 14-16.

AMERICAN INSTITUTE OF CONSULTING ENGINEERS, annual dinner meeting, New York, N. Y., Jan. 18.

NATIONAL CRUSHED STONE ASSOCIATION, annual convention, Cincinnati, Ohio, Jan. 18-20.

AMERICAN SOCIETY OF CIVIL ENGINEERS, annual meeting, New York City, Jan. 20-23.

ENGINEERING INSTITUTE OF CANADA, annual meeting, Montreal, Canada, Jan. 29-30.

ASSOCIATED GENERAL CONTRACTORS OF AMERICA, annual convention, San Antonio, Texas, Feb. 15-17.

AMERICAN CONCRETE INSTITUTE, annual meeting, New York, N. Y., Feb. 23-25.

AMERICAN RAILWAY ENGINEERING ASSOCIATION, annual meeting, Chicago, Ill., March 16-18.

NEW JERSEY SOCIETY OF PROFESSIONAL ENGINEERS AND LAND SURVEYORS, annual convention, Paterson, N. J., Jan. 16.

COLORADO SOCIETY OF ENGINEERS, annual meeting, Denver, Colo., Jan. 15-16.

LOUISIANA ENGINEERING SOCIETY, annual meeting, New Orleans, La., Jan. 22-23.

NEW YORK STATE SEWAGE WORKS ASSOCIATION, annual meeting, New York City, Jan. 21-23.

WYOMING SOCIETY OF ENGINEERS, annual meeting, Cheyenne, Wyo., Jan. 22-23.

AMERICAN WOOD PRESERVERS ASSOCIATION, annual meeting, New Orleans, La., Jan. 26-28.

NATIONAL PAVING BRICK ASSOCIATION, annual meeting, Detroit, Mich., Jan. 27-29.

CONNECTICUT SOCIETY OF CIVIL ENGINEERS, annual meeting, New Haven, Conn., Feb. 16-17.

SOUTHWEST ROAD SHOW AND SCHOOL, Wichita, Kansas, Feb. 23-26.

ASSOCIATION OF HIGHWAY OFFICIALS OF NORTH ATLANTIC STATES, annual convention, New York, N. Y., Feb. 24-26.

MINNESOTA FEDERATION OF ARCHITECTURAL AND ENGINEERING SOCIETIES, annual convention, St. Paul, Minn., Feb. 26-27.

NEW JERSEY SEWAGE WORKS ASSOCIATED, annual meeting, Trenton, N. J., March 11-12.

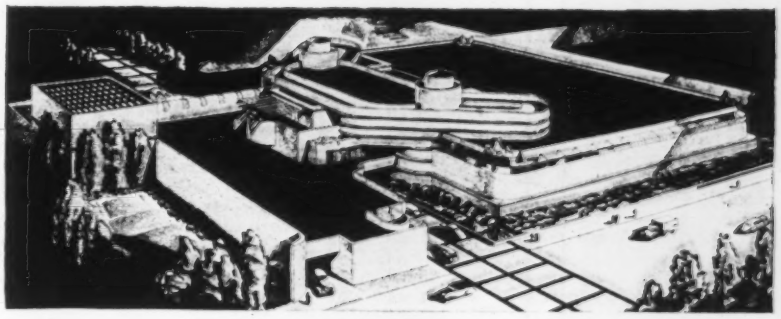
AMERICAN WATERWORKS ASSOCIATION, FOUR STATES SECTION, annual meeting, Hyattsville, Md., March 25-26.

AMERICAN WATERWORKS ASSOCIATION, FLORIDA SECTION, Jacksonville, Florida, March 30-April 1.

LICENSE EXAMINATIONS

NEW YORK Examinations for professional engineering originally scheduled for Jan. 25-27 have been postponed to Feb. 1-3, and the examination for land surveying originally scheduled for Jan. 28 has been postponed to Feb. 4.

Officers elected by the ENGINEERING ASSOCIATION OF NASHVILLE at a December meeting include President, E. M. Turner; vice president, W. W. Maddy; secretary-treasurer, John E. Thomas.



FUNCTION DICTATES FORM OF NEW INDUSTRIAL OFFICE BUILDING

WHAT is probably the most unusual industrial building in America is under construction in Racine, Wisconsin, to house the main office staff of S. C. Johnson & Son, Inc., makers of wax polishers. Its designer, Frank Lloyd Wright, famous for his architectural creations, disregards all convention, as has long been his practice, to produce what he describes as a "highly developed synthesis of form and idea—more highly developed than has been possible in the past because it is a building without windowed walls."

Function dictates form completely in an attempt to achieve both high working efficiency and extreme livability. Prominent in the sketch of the completed building reproduced here is the pent house in the shape of three ellipsoidal links containing the offices of the chief executives, the two circular breathing stacks or "nostrils" for intake and exhaust of air and the one-story structure at the left which is a roofed-over parking lot.

The plan centers around one large workroom, 210x130 ft., with a 20 ft. ceiling. Circling this room is a mezzanine gallery close to the first floor on which are located the offices of department heads and junior executives. The frame is of concrete and steel. The facade consists of brick and glass. The brick, of a soft red color, is of special size.

An interesting departure from conventional heating systems is the use of brass steam coils placed below the concrete floor slab to convert the floors themselves into radiators. Cork is used as insulation throughout. Utilities, as well as rest rooms, toilets, and locker rooms are all located below the large workroom and are reached directly by a series of spiral iron staircases. The building includes a small theatre with a seating capacity of 350 located on the mezzanine level. Orientation is an innovation in that the entrance is interior to the lot and faces the architectural parking area which is designed in keeping with the main structure. The main building is set back from the street fronts 14 ft. on all sides. The total estimated cost is over $350,000. The building will be ready for occupancy this summer. The general contractor is B. E. Wiltscheck, Racine, Wis.

$26,785,000 in PWA Funds Asked For New York Crosstown Tunnel

An application for federal aid in the construction of the proposed $26,785,000 tunnel under Manhattan Island connecting the Hudson River and East River midtown tunnels now under construction has been sent to the New York State PWA offices by borough president Levy of Manhattan.

Approval of the proposed vehicle tunnel, was voiced on Dec. 12 by the Merchants Association, an organization of New York business men. The association stated at the same time that the proposed tunnel was also approved by officials and engineers of the Tunnel Authority and the Port Authority.

The association pointed out that the Queens-Midtown tunnel under the East River would be opened in 1940 and that the first lane of the Midtown-Hudson tunnel will be ready for use in about a year and that the initial traffic in each of these tubes has been estimated at about 15,000,000 vehicles per year.

The Merchants Association's special committee on city transit, street traffic control, and public planning concluded, after a survey of midtown traffic conditions, that the completion of these river tubes would render the already congested traffic conditions in midtown Manhattan intolerable unless the proposed crosstown tunnel were built.

Western Mosquito Fighters Meet in Berkeley

Mosquito abatement officials, sanitary engineers, and health officers from California and Oregon met in Berkeley, Calif., at the University of California for the Seventh Annual Conference of Mosquito Abatement Officials on December 15.

Harold F. Gray, engineer of the Alameda County Mosquito Abatement District, pointed out the increasing interest of engineers and architects in problems of mosquito control. Mr. Gray stated that intelligent cooperation of engineers is needed in order that construction may be designed to prevent rather than to cause mosquito breeding and spoke of the interest in mosquito control work shown at the Portland Convention of the American Society of Civil Engineers.

Part of the conference program was devoted to a discussion of a slight, but apparently increasing, malarial incidence in California. Dr. Harlan L. Wynns, epidemiologist of the state department of Public Health, pointed out the danger of increased malaria resulting from an influx of migratory workers from southern states.

A. M. Emerick, superintendent of the Napa County Mosquito Abatement District, presided at the conference. Joseph C. Dickey, superintendent of Pulgas Mosquito Abatement District at Redwood City was elected president for the 1937 conference.

Brief News

THE BALTIMORE WATER TUNNEL from Loch Raven to Montebello is expected to be put under construction by early spring. Plans and specifications for the 8-mile, $5,300,000, tunnel have been placed in the hands of the Baltimore Public Improvement Commission by chief engineer Crozier, and the rights-of-way for the project have been acquired. When the new tunnel has been completed, in about three years, it is planned to line the present unlined tunnel between these two points at a cost of about $1,800,000.

THE FIRST ARGENTINE SECTION of the Pan-American Highway was opened to traffic on December 27 with the inauguration of the 222-mi. section from Buenos Aires to Rosario. This section was constructed at a cost of $7,500,000; it is 20 ft. wide and is paved with reinforced concrete, except for about 30 miles of macadam near Buenos Aires. The 200-mile section from Rosario to Cordoba will be opened to traffic in March, and work is well advanced on all sections of the 1,200-mile length of the Pan-American Highway in Argentina.

THE FIRST SECTION of Buffalo, N. Y.'s new $15,000,000 sewer project has been completed five days in advance of schedule. The completed section, known as Division G, was built by E. R. Morehouse & Co. of Camden, N. J., at a contract price of $228,000. Work began in June. All that remains to be done on this section is the laying of the permanent pavement, which will be done in the spring. This section of the sewer is divided into two parts, the first rectangular in shape, 71 ft. wide by 6 ft. high with a length of 1,488 ft. in open cut and the other consisting of 40 ft. of tunnel.

AN IMPOSING NEW BUILDING is to be constructed for the Bank of China in Shanghai, the completion date being set for next year. The building has a 100-ft. frontage and is 600 ft. deep. In the front is a tower 220 ft. high, said to be the tallest yet proposed in Shanghai. The building will be of steel frame construction with reinforced concrete and hollow tile floors and will be faced with granite. Foundation conditions make it necessary to support all the footings on timber piles 75 to 100 ft. long. According to the Carrier Engineering Corp., the main banking hall and all departments and individual offices will be air conditioned both in summer and in winter. At all times of the year the air will be dehumidified because of the prevailing excess moisture, and this dehumidification will vary automatically with the condition of the outside atmosphere. The architects and engineers for this project are Messrs. Palmer & Turner, of Shanghai and Hongkong, associated with H. F. Luke, architect in charge of the building department of the Bank of China.

PRELIMINARY PLANS for a bridge to carry Pennsylvania Ave. in Washington, D. C., across the Anacostia River have been approved by the National Capital Park and Planning Commission. One design in steel and one in concrete were selected for further study from a group of six drawings submitted by Colonel Sultan, engineer-commissioner, and Captain Whitehurst, director of highways, for the District of Columbia. A construction appropriation will be asked of the next Congress. The preliminary studies have been financed from a $25,000 grant made for this purpose by the last Congress.

THE WILLIAMSBURG BRIDGE over the East River in New York City has been given two extra lanes for highway traffic by the removal of two street car tracks. Originally the bridge carried two rapid transit tracks in the center, two sets of two-track trolley lines, one on each side, and two two-lane highways at the outer edges. By the present operation the trolley tracks, on which there is little traffic, are reduced to two, and six lanes of vehicle traffic are now available. The new vehicle lanes are paved with 7-in. concrete slabs reinforced with welded steel bar trusses prefabricated in mats. The work was done as a WPA project at a cost of about $400,000.

Personals

THELMA F. WHITE has been appointed deputy county engineer of Gallia County, Ohio. Mrs. White served as county engineer in 1934.

E. L. LINZELL has been appointed chief deputy engineer of Franklin County Ohio. Mr. Linzell was formerly assistant division engineer for the Ohio state highway department.

PERCY A. SHAW, engineer and superintendent of the Manchester, N. H. waterworks, has been appointed engineer member of the New Hampshire state board of health.

THOMAS M. RIDDICK, formerly associated with the late Nicholas F. Hill, Jr., has established a laboratory in New York City for the analysis of water and sewage and for testing sand and cement.

NELSON G. PHELPS has resigned as director of the project application section of the WPA engineering division to re-enter general construction engineering practice in Washington, D. C. and New York City.

PHILLIP B. STROYAN has been appointed assistant to the superintendent of the Vancouver Park Board. Mr. Stroyan is a graduate of the University of British Columbia.

BANUS H. PRATER, district engineer for the Union Pacific Railroad with headquarters in Salt Lake City, has been appointed chief engineer of the railroad with headquarters in Omaha. Mr. Prater has been connected with the Union Pacific since 1906.

LEE AIGHMY and JOSEPH DIMON, connected for 41 and 25 years, respectively, with the public works department of the city of Buffalo, N. Y., have been promoted to the grade of assistant city engineers of that city.

F. W. DANIELS has been appointed chief engineer of the H. K. Ferguson Co. of Cleveland, Ohio, in charge of engineering on all their projects. Mr. Daniels, a 1921 graduate in civil engineering from Cornell University, has been connected with the Ferguson Co. since 1924.

HOWARD C. MANN, chief engineer of the Union Pacific Railroad, has been appointed vice president in charge of operations. Mr. Mann is a graduate engineering of the University of Nebraska and has been connected with the Union Pacific since 1909 when he started as an instrument man. In 1918, Mr. Mann was appointed assistant engineer with offices at Omaha. The following year he was promoted to engineering accountant and in 1922 became assistant engineer in charge of bridge construction of the Oregon-Washington Railroad & Navigation Co., now the northwestern district of the Union Pacific. In 1924 he became chief engineer of the Union Pacific in charge of the southwestern district and four years later he returned to Omaha as chief engineer of the railroad.

Obituary

HARRY W. SMITH, 62, for the past six years city engineer of Jacksonville Beach, Fla. died in Jacksonville on Dec. 28.

LEONARD KENNEDY, president and director of the New York contracting firm of Carey, Baxter & Kennedy died in Port Chester, N. Y., Dec. 28, aged 50.

JAMES C. STEVENSON, connected since 1911 with the Chicago firm of H. L. Stevens & Co., architectural engineers, died in Chicago on Dec. 29 at the age of 51.

MILTON B. MORGAN, district engineer of the Illinois Central Railroad, died on Dec. 26 in Memphis, Tenn. at the age of 64. Mr. Morgan had been connected with the railroad since 1898.

GRIFFITH JOHN, formerly chief engineer of the Otis Elevator Company, of New York City, died on Dec. 30 in Plainfield, N. J. at the age of 81. Mr. John served with the elevator concern 50 years before his retirement 15 years ago.

WILLIAM J. SCULLY, president of W. J. Scully & Co., contractors of New York City, died in Great Neck, L. I., on Jan. 3 at the age of 47. Mr. Scully's firm had a part in the construction of many New York buildings, including the Ritz Tower, the Chrysler Building and the RCA Building.

WHITMAN P. CONN, editor of The Constructor, died in Washington, D. C. on Jan. 3. In 1930 Mr. Conn, a newspaper man, became publicity director of the Associated General Contractors of America and in 1934 was made editor of The Constructor, the organization's official publication.

PHILIP D. BORDEN, 86, city engineer, prior to his retirement in 1913, of Fall River, Mass., died in that city on Dec. 24. Mr. Borden was a graduate of the Massachusetts Institute of Technology. He had held the position of city engineer for 31 years before his retirement and had been connected with the city engineering department for more than 40 years.

EUGENE R. MYERS, member of the Seattle, Wash., contracting firm of Myers & Goulter, died on Dec. 20. Mr. Myers was connected before the war with the engineering staff of Clallan County, Wash. and afterwards was connected with the

Washington State Highway Department until 1921. His firm did much road-building for the federal government in Alaska.

HENRY LAWLER died on Dec. 21 in San Francisco at the age of 67. Mr. Lawler was vice president of the Utah Construction Co. and had been connected with many of the larger construction projects in the West. He was a director of Bridge Builders, Inc., contractors on the Bay Bridge, vice president of Six Companies, Inc., builders of Boulder Dam, and was connected with the construction of the Metropolitan aqueduct, Bonneville, Parker and Imperial dams, and the Hetch-Hetchy water system.

CHARLES HANSEL, until last year president of the Union County, N. J., Park Commission and for many years a consultant on valuation and economic problems for railroads, died in Punta Gorda, Fla. on Dec. 24, at the age of 77. Mr. Hansel, who studied civil engineering under a tutor, was for several years locating and construction engineer for the Denver and Rio Grande Railroad and was later division engineer for that railroad in charge of building their first division in New Mexico. From 1884 to 1889 he was chief engineer of the Wabash Railway. He was later first consulting engineer for the Illinois Railroad and Warehouse Commission. In 1901 he was appointed a member of the Michigan Board of Review to adjudicate railroad valuation problems, and from 1904 to 1906 served as a consulting engineer to the Indiana Harbor Railroad Company on the building of 110 miles of line. Mr. Hansel served as consulting valuation engineer for the Pennsylvania Railroad and its affiliated systems, as chairman of the valuation committee for the Philadelphia & Reading Railroad Co., the Central Railroad of New Jersey, and the Philadelphia Rapid Transit Co. In 1927 he organized the firm of Charles Hansel, consulting specialists.

CONSTRUCTION STATISTICS FOR THE WEEK

ENGINEERING construction awards for the first week of 1937 total $40,447,000. This comprises private work at $21,244,000; public, $19,203,000; federal, $3,704,000; state and municipal, $15,499,000. Corresponding values a week ago are: total, $43,020,000; private, $17,195,000; public, $25,825,000; federal, $1,425,000; state and municipal, $24,400,000. This week's volume in private work is due principally to large industrial building contracts in the South.

A gain is registered in public commercial and industrial buildings, and in sewerage, earthwork, and drainage, but all other classifications are lower. The classification subtotals are: industrial buildings, $15,709,000; commercial buildings, $4,271,000; public buildings, $9,067,000; highways, $4,029,000; bridges, $2,501,000; sewerage, $1,086,000; waterworks, $1,412,000; earthwork and drainage, $984,000; unclassified, $1,388,000.

New capital for the week includes state and municipal bond sales, $6,074,000; corporate security issues, $875,000, and PWA allotments, $240,000.

LARGER PROJECTS FOR THE WEEK

Paper mill, Southern Kraft Corp., Georgetown, S. C.	$8,000,000
Plant, American Cynamid Co., Valdosta, Ga.	600,000
Plant, Cleveland Twist Drill Co., East Cleveland, O.	500,000
Blast furnace, Hamilton Coke & Iron Co., New Miami, O.	1,000,000
Cracking unit, Tide Water Associated Oil Co., Avon, Calif.	1,500,000
Hospital, Israel Zion Hospital, Brooklyn, N. Y.	500,000
Exposition buildings, Public Utilities Comm., San Francisco, Calif.	1,182,000
Apex Building, Treasury Department, Washington, D. C.	3,105,000
Bridge, Delaware River Joint Toll Bridge Comm., Trenton, N. J.	723,000
Crystal Springs Pipe Line No. 2, San Francisco, Calif.	644,000
Williams Fork Tunnel in connection with sewage treatment work, Denver, Colo.	555,000

CONTRACTS
(Thousands of Dollars)

	Weekly Average Jan. 1936	Prev. 4 Weeks	Week Jan. 7 1936
Federal Government	$10,437	$4,380	$3,704
State and Municipal	38,655	17,993	15,499
Total public	$49,092	$22,373	$19,203
Total private	8,617	25,620	21,244
Week's total	$57,709	$47,993	$40,447
Cumulative to date: 1936	$36,736,000	1937	$40,447,000

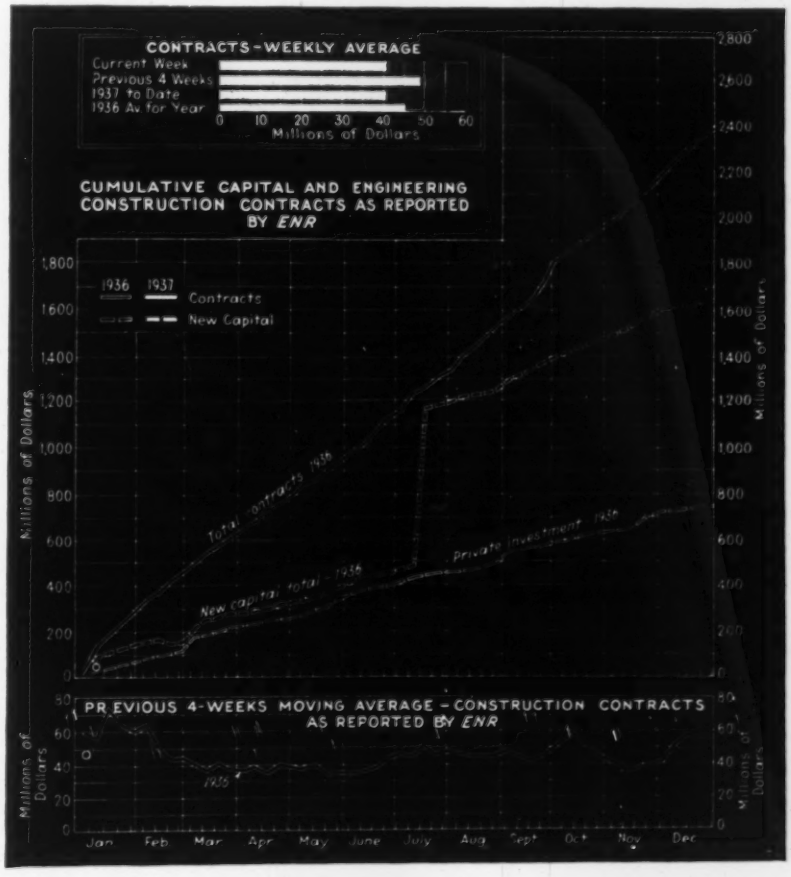
NEW PRODUCTIVE CAPITAL
(Thousands of Dollars)

1937	Week Jan. 7	Cumulative
State and municipal	$6,074	$6,074
PWA non-federal	875	875
FRC loans	....	....
RFC loans	....	....
Corporate issues	240	240
PWA loans, Private	....	....
Total Non-Federal	$7,189	$7,189
Federal	....	....
Total new capital	$7,189	$7,189
Cumulative to date: 1936	$10,794,000	1937 $7,189,000

Note: These figures include private bonds, and stocks sold for productive purposes; state and municipal bonds for construction; PWA loans and grants to states and municipalities. RFC direct purchase of bonds for "self liquidating" projects, and 25 per cent of WPA construction appropriations.

INDEX NUMBER

ENR Cost	1913 = 100	1926 = 100	ENR Volume	1913 = 100	1926 = 100
Jan. 1937	223.45	107.41	Dec., 1936	200	90
Dec., 1936	220.67	106.07	Nov., 1936	159	70
Jan., 1936	199.48	95.89	Dec., 1935	254	111
1936 (Av.)	206.46	99.24	1936 (Av.)	185	81
1935 (Av.)	195.22	93.84	1935 (Av.)	135	58
1934 (Av.)	198.10	95.23	1934 (Av.)	114	50


CONTRACTS - WEEKLY AVERAGE
Current Week
Previous 4 Weeks
1937 to Date
1936 Av for Year
0 10 20 30 40 50 60
Millions of Dollars
CUMULATIVE CAPITAL AND ENGINEERING CONSTRUCTION CONTRACTS AS REPORTED BY ENR
1936 1937
Contracts
New Capital
Millions of Dollars
Total contracts 1936
Private investment 1936
New capital total 1936
PREVIOUS 4-WEEKS MOVING AVERAGE - CONSTRUCTION CONTRACTS AS REPORTED BY ENR
1936
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec

CURRENT PRICES OF CONSTRUCTION MATERIALS

CEMENT, AGGREGATES AND READY-MIXED CONCRETE—F.O.B. CITY

	PORTLAND CEMENT (Per bbl., carload lots, including 40c per bbl. for bags, cash discount not included)			SAND AND GRAVEL (Per ton, carload lots)			CRUSHED STONE (Per ton, carload lots)		CRUSHED SLAG (Per ton, carload lots, f.o.b. plant)		CONCRETE
	Cloth Bags*	Paper Bags	Bulk	Gravel, 1½ in.	Gravel, ¾ in.	Sand	1½ in.	¾ in.	1½ in.	¾ in.	Ready Mixed 1:2:4, 5000 psi or more, delivered
Atlanta	$2.83	$2.58	$2.50	$1.60	$1.60	$1.55	$1.69	$1.92	$1.69	$1.69	$8.[illegible]
Baltimore	2.66	2.41	2.21	1.80‡	1.80‡	1.30‡	1.80‡	1.80‡	1.80	1.80	7.[illegible]
Birmingham	2.40	2.15	1.95	1.80	1.80	1.45	1.00	1.00	.90	1.15	5.[illegible]
Boston	2.25*dl*	2.00*dl*	1.80*dl*	1.20	1.20	.85	1.40	1.40	....	....	7.[illegible]
Chicago	2.50	2.25	2.10	1.50	1.50	1.50	1.80	1.80	1.00	1.00	....
Cincinnati	2.50	2.25	2.05	1.20	1.20	1.30	1.80	1.80	....	....	6.[illegible]
Cleveland	2.41	2.16	....	1.40	1.40	1.20	1.60	1.60	1.75	1.75	7.[illegible]
Dallas	2.30	2.05	1.85	1.40	1.40	1.05	1.10	1.15	1.84	1.89	7.[illegible]
Denver	3.08	2.85	....	1.20	1.40	.90	....	....	....	....	....
Detroit	2.25	2.00	1.80	1.30	1.30	1.20	1.50	1.60	1.40‡	1.50‡	5.[illegible]
Kansas City	2.51	2.26	2.06	1.85	1.85	1.15	1.85	1.80	....	....	7.[illegible]
Los Angeles	2.32	2.12	....	1.20	1.20	.90	1.20	1.20	....	....	6.[illegible]
Minneapolis	2.80	....	2.35	1.00*p*	1.00*p*	.25*p*	1.00*p*	1.00*p*	....	....	7.[illegible]
Montreal	....	2.62*S*	1.70	.80	.85	1.00	1.20‡	1.30‡	....	....	6.[illegible]
New Orleans	2.50	2.30	2.05	1.50	1.50	1.25	....	....	....	....	8.[illegible]
New York	2.35‡	2.10‡	....	1.10†*k*	1.10†*k*	.70†*k*	1.75†*k*	1.85†*k*	....	....	7.[illegible]
Philadelphia	2.58	2.33	2.13	1.45‡	1.55‡	1.15‡	1.85‡	1.90‡	1.00‡	1.03‡	8.[illegible]
Pittsburgh	2.46	2.21	1.61	1.50‡	1.50‡	1.70‡	2.25‡	2.25‡	1.50	1.50	7.[illegible]
St. Louis	2.53	2.28	....	1.60‡	1.40‡	1.25/1.40‡	.75*p*	.75*p*	.65/.95§	.50/.85§	6.[illegible]
San Francisco	2.72	2.52	2.20	1.35	1.35	1.35	1.50	1.50	....	....	7.[illegible]
Seattle	2.95	2.70	....	1.00	1.00	1.00	1.44	1.44	....	....	6.[illegible]

* 10c allowed for each returnable bag. † Per cu. yd. ‡ Delivered. § F.o.b. Granite City, Ill. *k* Barge lots alongside dock. *p* F.o.b. plant. *t* 5 tons or more *z* Within 3-mi. from Public Square. *t* ton. *d* 5% discount for cash. *dl* 10% off for cash 10 days. *D* Discount 35c. 500 to 2000; 70c. 2000 to 5000; 95c. over 5000. *S* Sales tax included.

CURRENT MAXIMUM PRICES RECEIVED AT CEMENT MILL

Charge for bags not included. For cloth bags, add 40c. per bbl.; 10c. refund allowed for each returnable bag; for paper bags add 15c. per bbl., not refundable.

	Bagged	Bulk		Bagged	Bulk		Bagged	Bulk
Alpena, Mich.	$1.50	$1.45	Ironton, Ohio	$1.50	$1.45	North Birmingham, Ala.	$1.75	$1.70
Buffington, Ind.	1.70	1.65	Iola, Kans.	1.70	1.65	Richard City, Tenn.	1.85	1.80
Crestmore, Calif.	1.72	....	La Salle, Ill.	1.70	1.65	Saginaw, Mich.	1.40	1.35
Dallas, Tex. (Inc. 5c. tax)	1.80	1.75	Limedale, Ind.	1.70	1.65	Steelton, Minn.	1.80	1.75
Hannibal, Mo.	1.70	1.65	Mason City, Ia.	1.70	1.65	Universal, Pa.	1.65	1.60
Hudson, N. Y.	1.75	1.70	Norfolk, Va.	1.76	1.71	Waco, Tex. (Plus 5c Tax in Texas)	1.75	1.70
Independence, Kans.	1.70	1.65	Northampton, Pa.	1.65	1.60	Wyandotte, Mich.	1.45	1.40

Cash Discounts, Cement to Contractors: truck delivery, 2% for cash on 10th of month; on carload deliveries, no trucking, same as dealer cash discount, 10c. per bbl. for payment within 15 days of date of invoice.

STRUCTURAL CLAY BUILDING TILE, BRICK AND LIME—DELIVERED

	STRUCTURAL CLAY TILE—PARTITION—SCORED (Per M, lots of 2,000 pieces or over, 3x12x12 in.)	(4x12x12 in.)	(8x12x12 in.)	STRUCTURAL CLAY TILE—LOAD BEARING—SCORED (Per M, lots of 2,000 pieces or over, 8x12x12 in.)	(10x12x12 in.)	(12x12x12 in.)	BRICK (Per M, in quantity, Common backing)	(Straight hard)	LIME (Per ton, Hydrated finishing)	(in paper, Common hydrated)	(carload lot, Pulverized or lump)
Atlanta	$71.10	$75.80	$142.10	$170.50	$199.00	$227.40	$12.25	$15.15	$19.50	$14.00	$14.00
Baltimore	91.00	98.00	183.00	219.00	315.00	390.00	13.00	17.00	20.00	14.00	25.00
Birmingham	78.75	84.00	157.50	189.00	201.25	242.00	15.00	19.00	3.00§	1.75§	2.25*e*
Boston	87.75*dl*	93.60*dl*	175.50*dl*	198.90*dl*	210.60*dl*	258.30*s*	15.00	18.50	20.00	15.50	3.50*f*
Chicago	66.00	70.40	132.00	174.30	214.40	245.00	10.20	11.20	18.00	13.40	14.00
Cincinnati	62.00	62.80	117.75	141.30	169.26	209.56	17.50	17.50	15.97	12.48	....
Cleveland	45.00	48.00	90.00	108.00	138.50	158.50	15.00	15.00	16.00*k*	14.00*k*	2.65*p*
Dallas	59.00	62.00	125.00	149.00	155.00	177.00	9.50	24.00	19.00	16.00	15.50*z*
Denver	78.50	88.00	141.50	160.65	196.00	225.50	11.50	15.00	30.00*k*	22.00*k*	22.50*z*
Detroit	71.85	76.65	143.70	230.00	280.00	325.00	12.50	13.50	18.00	15.00	15.25
Kansas City	64.50	66.50	81.00*	125.50	159.75	186.25	13.00	22.00	18.90	12.40	10.35
Los Angeles	77.50	94.25	134.00*	188.00	232.50	311.50	11.50	14.00	18.70	.....	19.70
Minneapolis	80.15*s*	85.50*s*	145.40*s*	167.75*s*	173.25*s*	243.70*s*	13.10	15.10*x*	21.00	16.00	19.00
Montreal	84.00*s*	96.00*s*	180.00*s*	.....	273.00	.....	15.50	20.75	25.50	17.00	11.00
New Orleans	69.00	69.00	129.00	155.05	203.25	251.70	13.00	.....	18.40	11.25	....
New York	78.40	83.60	125.40*	193.30†	238.80†	295.60†	12.50	.....	20.00	15.50	20.00
Philadelphia	80.50	85.90	161.10	193.30	234.40	290.10	15.00	18.00	16.30	11.10	10.60
Pittsburgh	58.40	62.30	116.85	165.00	217.00	250.00	16.50	25.00	17.20	14.50	2.22*p*
St. Louis	62.00	65.00	120.00	180.00	234.00	280.00	15.00	18.00	.55‡	.40‡	2.00*p*
San Francisco	84.00	94.50	225.00	.....	.....	.....	15.00	18.00	.55§	.40§	2.05*p*
Seattle	84.00	95.00	180.00	198.00	.....	.....	15.50*d*	18.50	30.00	20.00	28.60*f*

*6x12x12 in. † F.o.b. Perth Amboy, N. J. ‡ Per sack. § Per bbl., 200 lbs. *p* Per bbl., 180 lbs. *q* Per bbl., 280-lb. *k* LCL. *d* less $1 cash 15 days. *c* Lump. *s* Smooth. *x* Selected common. *l* Carload lots delivered to job. *z* Per sack, 100 lbs.

ROAD SURFACING MATERIALS—F.O.B. CITY

	PAVING BRICKS AND BLOCKS (Granite per M, lots of 50,000, 4x4x8 in.)	(Brick per M, 3x4x8½ in., carload lots)	(Wood per sq. yd., 3½ in. 16-lb. treat)	PAVING ASPHALT (Per ton, less than 80 penetration, Tank car)	(Drums)	ASPHALT BINDERS—FLUXES (Per gal., 80-300 penetration, Tank car)	(Drums)	CUTBACK ASPHALT (Per ton, Tank car)	(Drums)	ROAD OILS (Per gal., Tank car)	ASPHALT EMULSION (Per gal., Tank car)	(Drums)
Atlanta	$ 75.00	$35.00	$2.25	$18.20 ‡	$23.41 ‡	$0.028 ‡	$0.799 ‡	.0768†‡	.1089†‡	$0.668 ‡	$0.0875	$0.0875
Baltimore	110.00	44.00	2.25	17.00	22.00	.075	.10	.09†	.125†	.....	.....	.....
Birmingham	110.00	25.00	....	19.00	24.00	.0878	.1128	.10†	.137†	.....	.06	.....
Boston	75.00	46.00	3.00	17.00	22.00	.07*e*	.095*e*	.09†*e*	.125†*e*	.07*e*	.095*e*	.125*e*
Chicago	140.00	42.00	2.50	17.00	21.00	16.00	20.00	.07	.11	.045	.09	.135
Cincinnati	112.00	37.50	....	13.47	17.47	.12	.....	17.00	.....	.055	.08	.....
Cleveland	100.00‡	32.50	2.85	17.50	21.20	.075	.094	.085	.055†	.0575	.085	.095
Dallas	.....	32.50	....	18.00	21.75	.065	.16	18.75	26.25	.055	.085	.135
Detroit	.....	37.00	....	16.80*k*	21.00*k*	.....	.....	15.25	20.25	.055	.11	.15
Kansas City	.....	40.50	....	18.50	23.50	17.50‡	22.50‡	.077†	.107†	.057	.11	.15
Los Angeles	.....	50.00	....	10.34	14.50	10.34‡	14.50‡	10.34	.....	.042	.06	.12
Minneapolis	.....	.....	1.90*l*	18.20	24.70	.098*s*	.098	21.85	34.65	.048	.....	.....
Montreal	85.00*	60.00	3.62	14.00	20.00	.10	.13	.0975†	.1175†	.0675	.135	.165
New Orleans	100.00	32.00	....	15.20	18.75	.068	.095	.075†	.10†	.....	.0785	.11
New York	120.00§	65.00	2.75	17.00	22.00	.075	.10	.09†	.125†	.....	.075	.11
Philadelphia	120.00	42.00	....	15.00	20.00	.06	.085	.065†	.095†	.055	.07	.10
Pittsburgh	115.00	40.00	....	19.00	24.00	.077	.1125	.086†	.121†	.0675	.....	.....
St. Louis	115/120	35.00	....	19.20	24.20	.075	.105	.08†	.11†	.045	.09	.12
San Francisco	.....	50.00	....	12.00	18.00	12.00‡	18.00‡	12.50‡	23.00‡	.04	.0575	.117
Seattle	.....	35.00	....	25.50	25.50	17.00‡	23.00‡	15.00	.....	.03	.19	.20

Note: Paving asphalt, tank car or boat, f.o.b. Maurer, N.J., per ton, Bermudez, $25.00; Trinidad, $21.00. *Sales tax included. †Per gallon. ‡4¼x6x5½ in. ‡Per ton. § 4x5x9 in. Av. *k* Mexican. ‡ Local reduction due to 20% reduction intra-state class freight rates, only Georgia affected. *l* 2½ in. 6 to 8-lb. treatment. *e* F.o.b. Everett

CURRENT PRICES OF CONSTRUCTION MATERIALS

IRON AND STEEL PRODUCTS—BASE MILL PRICES

	STRUCT. SHAPES-PLATE	REINF. BARS ¼-in. billet	RIVETS ½-in. structural	WIRE NAILS Base	SHEET PILING Base	STEEL RAILS Per Gross Ton			TRACK SUPPLIES			
						Standard	Light	Re-rolled	Angle bars	Std. spikes	Tie plates	Track bolts
Birmingham	$2.20	$2.25	$3.15	$2.55	....	$39.00	$35.00	$34.00	$2.70	$2.90	$2.10	$4.00
Chicago	1.95	2.10	3.35	2.15	$2.50	39.00	35.00	34.00	2.70	2.90	2.10	4.00
Pittsburgh	2.05	2.05	3.25	2.25	2.25	39.00	35.00	34.00	2.70	2.90	2.10	4.00

IRON AND STEEL PRODUCTS—F.O.B. WAREHOUSE, PER 100 LB., BASE PRICE

F.O.B. WAREHOUSE	STRUCTURAL SHAPES Per 100 lb., base price	REINFORCING BARS Per 100 lb., ¼ in., base price		EXPANDED METAL LATH Per 100 sq. yd., carload lots		WELDED FABRIC REINFORCING Per 100 s.f., carload lots		6x6 in., No. 6 & 6 wires Per sq. yd.	SHEET PILING Per 100 lb. base price
		New billet	Rail steel	Std. diamond mesh, 3.4 lb.	Std. ribbed 3.4 lb.	4x16 in., No. 5 & 10 wires	4x12 in., No. 8 & 12 wires		
Atlanta	$3.49	$2.54	$2.37	$21.00	$23.00	$1.58	$1.20	$0.1494	$2.70
Baltimore	3.10	2.75	2.60	25.00	28.00	1.45	1.11	.1368	2.45
Boston	3.79	2.66	2.44	23.00†	25.00†	1.51	1.15	.1422	2.82
Chicago	2.10	2.10	1.95	20.00	22.00	1.44	1.11	.1359	2.50
Cincinnati	3.52	3.25	3.25	25.01	29.50	1.43	1.10	.1350	.....
Cleveland	3.31	2.75	2.60	20.00	22.00	1.42	1.09	.1332	.....
Dallas	2.45	2.65	2.60	26.00	28.00	1.69	1.27	.1593	2.85
Denver	4.05	3.76	3.61	22.00	25.00	1.70	1.27	.1611	.....
Detroit	3.52	2.64	2.49	20.00†	22.00†	1.45	1.11	.1368	2.53
Kansas City	3.85	2.85	2.75	19.00	21.00	1.55	1.18	.1467	2.94
Los Angeles	2.35	2.325	....	23.00	27.50	1.72	1.29	.1629	2.65
Minneapolis	3.70	3.06	2.91	24.00	28.00	1.54	1.17	.1458	2.82§
Montreal	3.25	2.15	2.15	32.50	35.50	2.46	1.82	.253	2.80
New Orleans	....	....	....	20.75	23.75	1.59	1.20	.1503	.....
New York	3.47	2.50	2.35	17.50	19.50	1.56	1.18	.1476	2.75
Philadelphia	3.10	2.76	2.21	18.50	21.50	1.46	1.12	.1377	2.40
Pittsburgh	2.07½‡	1.85‡	1.90‡	20.00‡	22.00‡	1.38	1.07	.1296	2.25
St. Louis	3.55	2.45/2.95	2.30/2.80	20.00/22.00	22.00/25.00	1.45	1.11	.1368	2.35
San Francisco	3.65	2.725	2.575	24.50	26.50	1.72	1.29	.1629	3.00
Seattle	3.55	2.50	....	24.50	26.50	1.72	1.29	.1629	2.60

‡Base Mill Price plus switching charge. Note: Shapes, bars and piling subject to quantity discounts. §Mill Price plus freight to Minneapolis. †f.o.b. delivered.

PAINTING AND ROOFING SUPPLIES—F.O.B.

	RED LEAD Per 100 lb. in 500-lb. lots Dry	WHITE LEAD Per 100 lb. in 500-lb. lots # in oil	READY-MIXED PAINT Per gal., drums			ROOFING SUPPLIES Carload lots, f. o. b. factory				
			Graphite*	Aluminum†	Ferric Oxide‡	Rolls, slate surfaced, 85-90 lb., per sq.	Asphalt felt, per 100 lb.	Tar felt, per 100 lb.	Asphalt coating per gal.	Tar pitch, 350 lb. bbl., per ton
Atlanta	$7.75	$11.50	$1.60	$2.50	$1.40	$1.94	$1.70	$1.70	$.36	$25.60
Baltimore	7.00	11.00	1.45	2.25	1.70	2.03	3.00	3.00	.35	25.00
Birmingham	7.25	11.50	2.35	2.35	1.85	2.01	1.77	1.77	.36	22.00
Boston	7.00	11.00	1.85	2.65	.0475x	1.75	2.25&	2.25&	.45	20.00
Chicago	7.00	11.00	1.80	....	....	2.35	2.16	2.16	.34	33.00
Cincinnati	7.00	11.00	1.45	2.50	1.40	2.40	2.39&	2.39&	.36	21.00
Cleveland	7.00	11.00	1.70	2.45	1.40	1.55	1.75&	1.75&	.23	19.00
Dallas	7.25	12.00	1.80	2.10	....	2.75&	2.50&	2.50&	.14	10.80
Denver	7.50	11.75	2.55	....	....	2.25	3.55	3.55	.35	30.00
Detroit	7.00	11.50	1.65	2.40	1.40	2.40	2.65	2.50	.35	30.00
Kansas City	7.00	11.12½	1.65	2.65	1.10	1.78	3.15	3.15	.25	24.50
Los Angeles	7.25	11.25	1.60	2.25	2.30	2.00	1.50	....	.45	.....
Minneapolis	7.00	11.12½	....	....	....	1.75v	1.62&v	1.62&v	.29	23.80
Montreal	....	8.20	2.00	4.75	2.40	2.50	1.60	1.83	.50	1.52§
New York	7.00	11.00	1.85	2.50	1.55	1.75	1.62&	1.62&	.232	22.00
Philadelphia	7.00	11.00	2.515	2.94	1.515	1.75	1.86&	1.48&	.29	25.00
Pittsburgh	7.00	11.00	1.05	1.95	.80	1.84	1.65&	1.65	.34	24.00
St. Louis	10.00	11.00	1.60/1.85	2.40/2.45	1.40/1.70	1.83&	2.57	2.57	.25	25.00
San Francisco	7.25	11.25	1.80	2.75	1.10–2.00	1.54	1.90	1.90	.325	22.00
Seattle	7.25	11.25	1.80	2.85	2.20	1.97	2.42	2.60	.60	28.00

*U. S. War Dept. Spec. 3-49A. †ASTM Spec. D266-31. ‡80% maximum ferric oxide. §Per 100 lb. &Per roll, 65 lb. xPer lb. vMinneapolis & vicinity
Note: Red lead in oil 50c higher than white lead in oil. #Basis of quoting changed this month from list to 500-lb. lots. aSales Tax included.

MISCELLANEOUS ITEMS

WINDOW GLASS

Discounts from latest jobbers List, Sept. 15, 1928

	Single or Double Thickness A quality	B quality
Atlanta	75%	75%
Baltimore	84%	86%
Birmingham	80%	90%
Boston	87%	88%
Chicago	86%	87%
Cincinnati	89–10%	91–10%
Cleveland	85%	85%
Dallas	80%	80%
Denver	86%	87%
Detroit	87–10%	89–10%
Kansas City	85–10%	86–10%
Los Angeles	90%*	90–40%
Minneapolis	84%	85%
Montreal	60–30%	70–5%
New Orleans	88%	90%
New York	85%	87%
Philadelphia	85%	86%
Pittsburgh	88%	80%
St. Louis	80%	89%
San Francisco	70%	83%
Seattle	83%	86%

*Disc. from list Aug. 1, 1929. †F.o.b. Arsenal. ‡Double thickness A & B.
xManhattan only – other Boroughs $6 per trip. c carload lots.

EXPLOSIVES

Per lb. dynamite delivered 50-lb. cases

	Gelatin 40%	60%
Atlanta	$0.135	$0.15
Baltimore	.145	.16
Birmingham	.095	.11
Boston	.13	.145
Chicago	.105c	.12c
Cincinnati	.27	.29
Cleveland	.215	.225
Dallas	.16	.170
Denver	.15	.16
Detroit	.21	.24
Kansas City	.15	.165
Los Angeles	.1725†	.1925†
Minneapolis	.145	.16
Montreal	.18	.1925
New Orleans	.215	.23
New York	.215x	.23x
Philadelphia	.145	.16
Pittsburgh	.10	.115
St. Louis	.145	.165
San Francisco	.1475	.1625
Seattle	.1425	.1575

CHEMICALS

Water, sewage treatment, road work, f.o.b. carlots, New York.

Bleaching powder, in drums, F.o.b. works, per 100-lb	$2.00–2.85
Calcium chloride, 77–80% flaked, in 400-lb. drums or 100-lb. moisture proof bags, f.o.b works freight equalized with points of competition, per ton	22.00–35.00
Chlorine cylinders per lb delivered	.055
Silicate o soda 52 deg., in drums, f.o.b. works, per 100 lb	1.35
Soda ash, 58% in paper bags, per 100 lb. dense	1.25
Sulphate of aluminum, commercial, in 100-lb. bags, per ton	27.00
Sulphate of copper, in bbl., per 100-lb	4.45

PILES

Prices per linear foot, pine, with bark on, f.o.b. New York; delivered from barge 1½ to .c. per ft. additional:

Dimensions	Points	Length	Short Leaf Barge	Short Leaf Rail	Long Leaf Barge	Long Leaf Rail
12 in. at butt	6 in.	30 to 50 ft.	$0.16	$0.195	$0.16	$0.19
12 in.—2 ft. from butt	6 in.	50 to 59 ft.	.20	.24	.18	.23
12 in.—2 ft. from butt	6 in.	60 to 69 ft.	.21	.255	.19	.24½
14 in.—2 ft. from butt	6 in.	50 to 69 ft.	.23	.265	.23½	.27½
14 in.—2 ft. from butt	6 in.	70 to 79 ft.	.25	.275	.27½	.33½
14 in.—2 ft. from butt	5 in.	80 to 85 ft.	.35	.415	.....	.....
14 in.—2 ft. from butt	5 in.	85 to 89 ft.	.37	.432	.....	.....

RAILWAY TIES

	Prices f.o.b., per tie, for carload lots:	6 In. x 8 In. by 8 Ft.	7 In. x 9 In by 8½ Ft.
Boston	Oak, untreated	$1.10	$1.50
	Pine, untreated	1.10	1.50
	Pine, creosoted	1.60	2.25
New York	Long-leaf sap pine, untreated	1.05	1.25
	Mixed oak, untreated	1.20	1.40
	White oak, untreated	.85	1.35
	White oak, creosoted	1.50	1.70
Birmingham	Southern pine, untreated *6 x 8 x 8' 6"	.55*	.70
	Southern pine, creosoted	1.10*	1.30
Chicago	White oak, untreated	1.25	1.55
	Oak, empty cell, creosoted	1.67	2.05
	Oak, zinc treated	1.55	1.90
	Southern pine, creosoted	1.50	1.95
Los Angeles	Fir, untreated	.50	.72
	Fir, creosoted	1.67	2.40
Philadelphia	Red oak, untreated	1.00	.....
	Red oak, creosoted	.....	2.10
St. Louis	White oak, untreated	1.05	1.45
	Red oak, untreated	1.02	1.40
	Red oak, creosoted	1.55	1.95
San Francisco	Sap pine or cypress, untreated	.87	1.20
	Douglas fir, green, untreated	.45	.63
	Douglas fir, empty cell, creosoted	1.14	1.56
Montreal	Birch or maple, untreated	.65	.75
	Birch or maple, creosoted	1.05	1.35

CURRENT PRICES OF CONSTRUCTION MATERIALS

PLUMBING, HEATING, WATER, SEWER AND DRAIN PIPE

	C. I. PIPE	VITRIFIED SEWER PIPE				CLAY DRAIN TILE		CONCRETE SEWER PIPE		WROUGHT STEEL PIPE Full standard weight. ‡			
	Per net ton, f.o.b. 6 in. to 24 in.*	Per foot, delivered, ASTM C 13-35 8 in., s.s.	12 in., s.s.	24 in., d.s.	36 in., d.s.	Per 1,000 ft., carload lots., f.o.b. 6 in.	8 in.	Per ft., delivered; ASTM C 14-35 12 in.	24 in.	1 to 3 in., Butt Weld Black %	Galv. %	3½ to 6 in., Lap Weld Black %	Galv. %
Atlanta	$45.00	$0.25dl	$0.45dl	$1.6251	$4.501	$85.00	$128.00	$0.45	$1.625	49.5	40.5	47	32.5
Baltimore	48.50	.28	.54	2.38	7.18	110.00	170.00	.40	1.60	.....	.....	.....	.....
Birmingham	41.00	.25	.45	1.625	4.66	85.00	220.00	.40	1.60	69.5	61.5	67	58.5
Boston	48.50	.224	.432	1.98	5.845	99.00	153.00	.43	2.40	.....	.....	.....	.....
Chicago	49.50	.245	.4725	2.025	4.60	60.00	120.00	.36	1.42	58.75	48.75	55.625	45
Cincinnati	48.00	.189	.3645	1.62	5.535	69.00	108.00	.40	1.40	58.75	48.75	55.625	45.00
Cleveland	49.50	.182	.351	1.53	4.8175	69.00	108.00	.32	1.64	61	51	57.9	47.25
Dallas	53.00	.40	.....	.....	.....	160.00	260.00	.46	1.57	69.5	61.5	67	58.5
Denver	61.00	.27‡	.47‡	1.98‡	.....	105.00	180.00	....	.....	50	40	47	36
Detroit	49.50	.203	.3915	1.71	5.2375	82.00	136.00	.35	1.20	59.3	49.3	56.1	45.5
Kansas City	51.00	.30	.54	2.16	5.00	120.00	140.00	.40	1.50	55	45	51.5	41
Los Angeles	49.50	.2825‡	.508‡	2.03‡	5.535‡	115.50	192.50	1.00	2.00	62.1	54.1	59.6	51.1
Minneapolis	51.50	.24‡	.432‡	1.728‡	4.60‡	.....	.....	.65	1.75	.....	.....	.....	.....
Montreal	50.00	.33‡	.59‡	2.04‡	.....	82.00	134.00	.51	2.04	.....	.....	.....	.....
New Orleans	47.00	.23	.41	1.60	.....	67.00	.....	.47	1.67	.....	.....	.....	.....
New York	48.00	.24	.49	2.20	6.10	.....	.....	.55	2.00	57.50z	47.50z	54.375z	43.75z
Philadelphia	45.00	.196	.378	1.755	5.33	100.00	150.00	.54	1.80	52.37z	41.35z	53.39z	42.57z
Pittsburgh	51.00	.168‡	.324‡	1.35‡	4.92‡	52.00	81.00	.75c	1.75	69.5	61.5	67	58.5
St. Louis	48.00	.25	.45	1.83	3.96	85.00	170.00	1.00	2.25	57.125	47.125	54	43.375
San Francisco	49.00	.29L	.522L	2.088L	5.67L	103.50	172.50	.45	2.10	59	49	52	41
Seattle	50.50	.420	.63†	3.06†	7.55†	85.00	200.00†	.50†	1.60	65.80	57.25	66.75	56.30

* b. & s. class B and heavier, C/L lots, 200 tons and over. Burlington, N. J. (base) $45.00. Gas pipe and class A; $3 per ton additional. 4 in., $3 per ton additional. 30 in. and larger usually $2 per ton less.

‡ Discounts from standard list for delivery from warehouse, except Pittsburgh prices are f.o.b. mill. Base price $200 per net ton. List prices per ft.: ¾ in., 8½c.; 1 in., 11½ c.; 1¼ in., 17c.; 2 in., 37c.; 2½ in., 58½c.; 3 in., 76½ c.; 4 in., $1.09; 6 in., $1.92.

d 2½ to 3 in. z Resale price to consumer, car load lots shipped from mill.

f.o.b. † Less 30% in C/L Lots. c Concrete Culvert pipe reinforced. d Double strength. l List to dealers. L list. t Sales & municipal taxes extra.

LUMBER AND TIMBER—PER M FT. B.M., CARLOAD LOTS F.O.B.

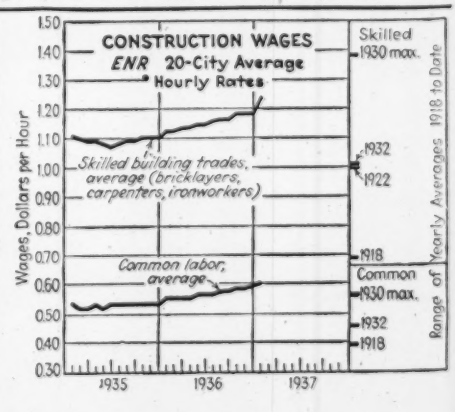
	SHORT LEAF YELLOW PINE AND DOUGLAS FIR— All S. L. Y. P. is No. 2 common or better and for No. 1 N. C. Box. (Prices in Bold Face). *All Fir planks No. 2 common; Fir timber is No. 1 common. Lengths up to 20 ft. (Prices in italics)*									LONG LEAF Y. P. Merchantable grade up to 20 ft.		PLYWOOD Rail freight increment (See note)	
	1x6.s	1x8.s	2x4.s	2x6.s	2x8.s	2x10.s	3x12.s	6x12.s	12x12.s	2x12.s	12x12.s	⅝"	¾"
Atlanta	**$20.00**	**$20.00**	**$21.50**	**$20.50**	**$21.00**	**$24.00**	**$26.00**	.....	.....	$42.00	$45.00	$16.80	$20.50
Baltimore	**25.50**	**26.00**	**28.50**	**27.50**	**29.00**	**30.50**	**41.00**	.....	.....	58.00	59.00	16.45W	20.05W
	32.00	*32.00*	*31.00*	*30.50*	*30.50*	*31.00*	*33.50*	*$35.50*	*$34.00*	.....	.....	.....	.....
Birmingham	**22.00**	**22.00**	**22.00**	**21.00**	**22.00**	**26.00**	**30.00**	**30.00**	**29.00**	.....	.....	15.55	18.95
[1]	23.00	23.00	26.00	25.00	26.00	32.00	45.00	.....	.....	48.00	48.00	.....	.....
Boston	32.00[2]	32.00[2]	35.00[3]	35.00[3]	51.00[1]	60.00[1]	75.00[1]	.....	.....	75.00	75.00	16.45W	20.05W
	32.00	*32.00*	*35.00*	*35.00*	*40.00*	*40.00*	*45.00*	*48.00*	*43.00*	.....	.....	.....	.....
Chicago	**32.00**	**32.00**	**30.00**	**30.00**	**30.00**	**31.00**	**50.00**	.....	.....	60.00	60.00	12.45	15.15
Cincinnati	**25.50**	**25.50**	**25.50**	**24.50**	**25.50**	**28.50**	**39.50**	.....	.....	41.00	44.00	15.55	18.95
	.....	.....	.....	.....	.....	.....	*43.75*	*43.75*	*43.75*	.....	.....	.....	.....
Cleveland	**30.00**	**32.00**	**38.00**	**32.00**	**36.00**	**38.00**	**49.00**	*44.00*	*43.75*	52.00	64.00[8]	15.55	18.95
Dallas [d]	**37.50**	**39.00**	**40.00**	**40.00**	**41.00**	**42.50**	**61.50**	*76.50*	*66.50*	62.65	76.50	13.15	16.05
Denver [*]	*42.00*	**42.00**[4]	*43.00*	*43.00*	*43.00*	*47.00*	*52.00*	*56.00*	*61.50*	.....	.....	9.35	11.33
Detroit	**30.00**	**30.00**	**30.00**	**30.00**	**30.00**	**31.00**	**39.00**	.....	.....	32.00	44.00	15.55	18.95
	.....	.....	.....	.....	.....	.....	*47.50*	*47.50*	*52.00*	34.00	46.00	.....	.....
Kansas City	**29.00**	**29.00**	**27.00**	**26.50**	**27.50**	**28.00**	**37.00**	.....	.....	52.00	60.00	11.45	13.95
	28.00	*28.00*	*29.00*	*28.00*	*29.00*	*29.00*	*35.00*	*38.00*	*33.00*	.....	.....	.....	.....
Los Angeles [†]	*37.00*	*36.00*	*37.00*	*36.00*	*38.00*	*38.00*	*40.00*	*51.00*	*46.00*	.....	.....	8.90WX	10.80WX
Minneapolis [*‡]	45.00[8]	51.50[8]	50.00[8]	41.00[8]	41.00[8]	42.00[8]	.....	.....	.....	58.00[5]	.....	11.45	13.95
[*]	*42.00*	*42.00*	*43.00*	*43.00*	*43.00*	*43.00*	*55.00*	*59.50*	*59.50*	54.00	.....	.....	.....
Montreal [7]	45.00	45.00	49.00	47.00	48.00	58.00	.....	.....	.....	.....	.....	.....	.....
	39.50	*39.50*	*40.00*	*40.00*	*40.00*	*41.50*	*42.00*	*42.00*	*42.00*	82.00	76.00	.....	.....
New Orleans	**23.50**	**25.50**	**28.00**	**25.00**	**27.00**	**25.50**	**38.00**	.....	.....	44.00	54.00	13.15	16.05
	28.50	*30.00*	*33.00*	*29.00*	*32.00*	*33.50*	*37.00*	.....	.....	.....	.....	.....	.....
New York [*]	**35.00**	**36.00**	**36.00**	**37.00**	**37.00**	**38.00**	**45.00**	.....	.....	75.00	77.50	16.45W	20.05W
[*]	.....	.....	*42.50*	*42.50*	*42.50*	*44.00*	*45.00*	*47.50*	*47.50*	.....	.....	.....	.....
Philadelphia	**28.50**	**28.50**	**28.50**	**29.00**	**29.50**	**30.50**	**38.50**	.....	.....	60.00	60.00	16.45W	20.05W
[9]	*45.00*	*45.00*	*45.00*	*45.00*	*45.00*	*45.00*	*45.00*	*42.00*	*42.00*	.....	.....	.....	.....
Pittsburgh	**38.10**	**39.90**	**47.05**	**42.00**	**45.65**	**46.90**	**59.70**	.....	.....	57.50	57.50	16.20	19.70
	51.90	*49.60*	*49.60*	*49.00*	*48.90*	*49.25*	*66.55*	*66.55*	*66.55*	.....	.....	.....	.....
St. Louis [*§]	**32.50**	**33.50**	**32.00**	**31.00**	**32.00**	**33.00**	**47.00**	*55.00*	*55.00*	72.00	71.00	13.15	16.05
San Francisco. [s]	*20.50*	*20.50*	*21.00*	*21.00*	*21.50*	*22.50*	*22.00*	*22.00*	*22.00*	.....	.....	6.95W	8.50W
Seattle	*16.50*	*16.50*	*16.50*	*15.50*	*15.50*	*15.50*	*21.00*	*20.00*	*20.00*	.....	.....	0.00	0.00

[s] S4S. [s] Rough. * All prices delivered. † Yard prices. ‡ Contractors in Minneapolis & St. Paul get 15% disc. from list. § 5M ft. or less [s] At ship's tackle. d10% Disc. taken off. [1] Long leaf. [2] Roofers N.C. Pine. [3] Spruce. [4] Native. [5] Northern Pine. [7] Western Pine. [7] Pine. [8] Norway Pine. [9] Dec. prices, Jan. prices not available due to strike. Bold face type, Southern Pine. Italics, Douglas Fir.

Note: Special concrete form grade Plywood, 4'x8' panels, 5-ply, sanded 2 sides, water resistant glue, car load lots, delivered, per 1000 sq. ft. surface. Base price — Seattle: ⅝", $63.75; ¾", $72.75. For other centers add rail freight increment from table for proper size.

W Lower rate by water shipment. X 50,000 lb. minimum.

CURRENT BUILDING AND CONSTRUCTION WAGE RATES PER HOUR

	Bricklayers	Carpenters	Structural Iron Workers	Hoisting Engineers	Plasterers	Common Labor Building	Common Labor Heavy Const.
Atlanta	$1.125	$0.40/1.00	$1.25	$1.00/1.25	$1.00	$0.30/.40	$0.30/.40
Baltimore	1.25	1.10	1.37½	1.25	1.25	.45	.45
Birmingham	1.00	1.00	1.25	1.125	1.00	.30/.40†	.30/.40†
Boston	1.50	.90/1.375	1.375	1.00/1.375	1.625	.60/.80	.60/.85
Cincinnati	.80/1.375	.65/1.20	1.25	1.00/1.25	.80/1.375	.45	.45
Chicago	1.50	1.50	1.50	1.50	1.50	.95	.95
Cleveland	1.375	1.25	1.25	1.25	1.50	.825	.825
Dallas	1.25	1.00	1.00	1.00	1.25	.40	.40
Denver	1.25	1.25	1.25	.....	.....	.625	.625
Detroit	1.25	1.00	1.25	1.25	1.25	.50/.75	.60
Kansas City	1.325	1.25	1.25	1.25	1.45	.80	.45/.50
Los Angeles	1.10	1.10	1.125	1.125	1.25	.60	.60
Minneapolis	1.25	1.10	1.25	1.25	1.35	.75	.75
New Orleans	1.00	.75	1.00	1.00	1.25	.30/.40	.30/.40
New York	1.50	1.40	1.65	1.50/1.5625	1.50	.82½	.50/.80
Philadelphia	1.50	1.00	1.375	1.50	1.375	.40/.50	.40/.50
Pittsburgh	1.50	1.25	1.375	1.00	1.50	.70	.50
St. Louis	1.50	1.25	1.47	1.57/.75	1.50	.78½	.35/.78½
San Francisco	1.50	1.125	1.37½	1.12½	1.50	.875	.60
Seattle	1.50	1.125	1.25	1.25	1.50	.80	.80
Montreal	.70	.60	.65	.55	.70	.40	.35

Skilled Avg.: (Bricklayers, Carpenters, Ironworkers) $1.240; Common Avg. $0.603. † PWA.